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TERRESTRIAL ENVIRONMENT (CLIMATIC) CRITERIA GUIDELINES FOR USE IN SPACE VEHICLE DEVELOPMENT, 1966 REVISION

By Glenn E. Daniels, James R. Scoggins and Orvel E. Smith

Aero-Astrodynamics Laboratory

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ABSTRACT

This document provides guidelines on probable climatic extremes and probabilities-of-occurrence of terrestrial environment data specifically applicable for NASA space vehicles and associated equipment development. The geographic areas encompassed are the Eastern Test Range (Cape Kennedy, Florida); Huntsville, Alabama; New Orleans, Louisiana; the Western Test Range (Point Arguello, California); Sacramento, California; Wallops Test Range (Wallops Island, Virginia); White Sands Missile Range, New Mexico; and intermediate transportation areas. In addition, a section has been included to provide information on the general distribution of natural environment extremes in the United States (excluding Alaska and Hawaii) that may be useful to specify design criteria in transportation of space vehicle components from subcontractors. This document omits climatic extremes for worldwide operational conditions. This is consistent with the existing philosophy regarding the employment of large space vehicles, since launching and test areas are relatively restricted due to the availability of facilities and real estate.

This document presents the latest available information on probable climatic extremes, and superseded information presented in TM X-53023 (Ref. 1.2). The information in this document is recommended for employment in the development of space vehicles and associated equipment, unless otherwise stated in contract work specifications.

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SUMMARY

This document provides guidelines on probable climatic extremes and probabilities-of-occurrence of terrestrial environment data specifically applicable for NASA space vehicles and associated equipment development. The geographic areas encompassed are the Eastern Test Range (Cape Kennedy, Florida); Huntsville, Alabama; New Orleans, Louisiana; the Western Test Range (Point Arguello, California); Sacramento, California; Wallops Test Range (Wallops Island, Virginia); White Sands Missile Range, New Mexico; and intermediate transportation areas. In addition, a section has been included to provide information on the general distribution of natural environmental extremes in the United States (excluding Alaska and Hawaii) that may be needed to specify design criteria in transportation of space vehicle components from subcontractors. This document omits climatic extremes for worldwide operational conditions.* This is consistent with the existing philosophy regarding the employment of large space vehicles, since launching and test areas are relatively restricted due to the availability of facilities and real estate.

This report establishes design guideline values for the following environmental parameters: (1) thermal (temperature and solar radiation), (2) humidity, (3) precipitation, (4) winds, (5) pressure, (6) density, (7) electricity (atmospheric), (8) corrosion (atmospheric), (9) sand and dust, (10) fungi and

* Re-entry landing areas are not covered in this report.

bacteria, (11) atmospheric oxidants, (12) composition of the atmosphere, and (13) inflight thermodynamic properties. Data are presented for various percentiles and discussions of the data relative to interpretation as design guidelines are also presented. Additional information on the different parameters may be located in the numerous references cited in the text following each section.

Questions pertaining to information presented in this document should be directed to the appropriate author(s).

FOREWORD

For climatic extremes, there is no known physical specific upper or lower bound, except for certain conditions; that is, for wind speed there does exist a strict phys al lower bound of zero. Therefore, for any observed extreme condition there is a finite probability of its being exceeded. Consequently, climatic extremes for design must be accepted with the knowledge there is some risk of the values being exceeded. Also, the accuracy of measurement of many of the environmental parameters is not as precise as desired. In some cases, theoretical estimates of extreme values are believed to be more representative than those indicated by measurements. Therefore, theoretical values are given considerable weight in selecting extreme values for some parameters, i.e., the low level wind profiles.

With regard to ground and in-flight winds, shears, and turbulence, it is understood that the space vehicle will not be designed for launch and flight in severe weather conditions; that is, hurricanes, thunderstorms, and squalls. Wind conditions are presented for various percentiles based on available data samples. Caution should be exercised in the interpretation of these percentiles in vehicle studies to ensure consistency with physical reality.

Environmental data in this document are limited to information below 100 km. The document,* NASA TM X-53273 "Space Environment Criteria Guidelines for Use in Space Vehicle Development, (1965 Revision)" (Ref. 1.1), provides information above 100 km. Specific space vehicle natural environmental design criteria are specified in the appropriate organizational space vehicle design ground rules and design criteria data documentation.

Considerably more information is available, but not in final form, on some of the topics in this document, viz., solar radiation, and surface and in-flight winds and thermodynamic properties. It is therefore recommended that users of this document who require data that are not provided or are inadequate

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* In process of revision at this time (May 1966).

for NASA approved programs, submit a request through appropriate organizational channels to the Aerospace Environment Division, (R-AERO-Y), Aero-Astrodynamics Laboratory, Marshall Space Flight Center, for the required information. An effort will be made to provide the required data and their interpretation in a suitable form for the specific design or operational problem.

This document is a revision and should be used in lieu of the data presented in TM X-53023 (Ref. 1.2). This document, therefore, replaces and supersedes for design or operational use NASA TM X-52023. The information in this document is recommended for employment in the development of space vehicles and associated equipment, unless otherwise stated in contract work specifications.

SECTION I. INTRODUCTION

1.1 General

A knowledge of earth atmosphere environmental parameters is necessary for the establishment of design requirements for space vehicles and associated equipment. Such data are required to define the design condition for fabrication, storage, transportation, test, pre-flight, and in-flight design conditions and should be considered for both the whole system, the components, and the parts which make up the system. The purpose of this document is to provide guideline data on natural environmental conditions for the various major geographic locations which are applicable to the design of space vehicles and associated equipment for the National Aeronautics and Space Administration. The publications MIL-STD-210A (Ref. 1.3), U. S. Standard Atmosphere, 1962 (Ref. 1.4), the Air Force Interim Supplemental Atmospheres (Ref. 1.5), and the Range Reference Atmospheres (Ref. 1.6), are suggested for use as sources of data for geographic areas not given in this document.

Good engineering judgement must be exercised in the application of the earth's atmospheric data to space vehicle design analysis. Consideration must be given to the overall vehicle mission and performance requirements. Knowledge still is lacking on the relationships between some of the atmospheric variates which are required as inputs to the design of space vehicles. Also, interrelationships between space vehicle parameters and atmospheric variables cannot always be clearly defined.

It is neither economically nor technically feasible to design space vehicles to withstand all atmospheric extremes. For this reason, consideration should be given to protection of space vehicles from some extremes by use of support equipment, and by using specialized forecast personnel to advise of the expected occurrence of critical environmental conditions. The services of specialized forecast personnel may be very economical in comparison to more expensive designing which would be necessary to cope with all environmental possibilities.

This document does not specify how the designer should employ the data in regard to a specific space vehicle design. Such specifications may be established only through analysis and study of a particular design problem. Although of operational significance, descriptions of some atmospheric conditions, i.e.,

cloud cover, visibility, etc., have been omitted since they are not of concern for structural and control system design. As an example Reference 1.7 and 1.8 contain an analysis of Cape Kennedy cloud cover data.

Induced environments (vehicle caused) may be more critical than natural environments for certain vehicle design problems and in some cases the combination of natural and induced environments will be more severe than either environment alone. Induced environments are considered in other space vehicle criteria documents and should be consulted for such data.

1.2 Geographical Areas Covered (Fig. 1.1)

a. Huntsville, Alabama.

b. River transportation: Between Huntsville, Alabama (via Tennessee, Ohio, and Mississippi Rivers) and New Orleans, Louisiana.

c. New Orleans, Louisiana; Mississippi Test Operations, Mississippi; Houston, Texas, and transportation zones between these locations.

d. Gulf transportation: Between New Orleans, Louisiana (via Gulf of Mexico and up east coast of Florida) and Cape Kennedy, Florida.

e. Panama Canal transportation: Between Los Angeles or Point Arguello, California (via West Coast of California and Mexico, through the Panama Canal, and Gulf of Mexico) and New Orleans, Louisiana.

f. Eastern Test Range (ETR), Cape Kennedy, Florida.

g. Western Test Range (WTR), Point Arguello, California.

h. Sacramento, California.

i. Wallops Test Range, Wallops Island, Virginia.

j. West coast transportation: between Los Angeles, California, and Sacramento, California.

k. White Sands Missile Range, New Mexico.

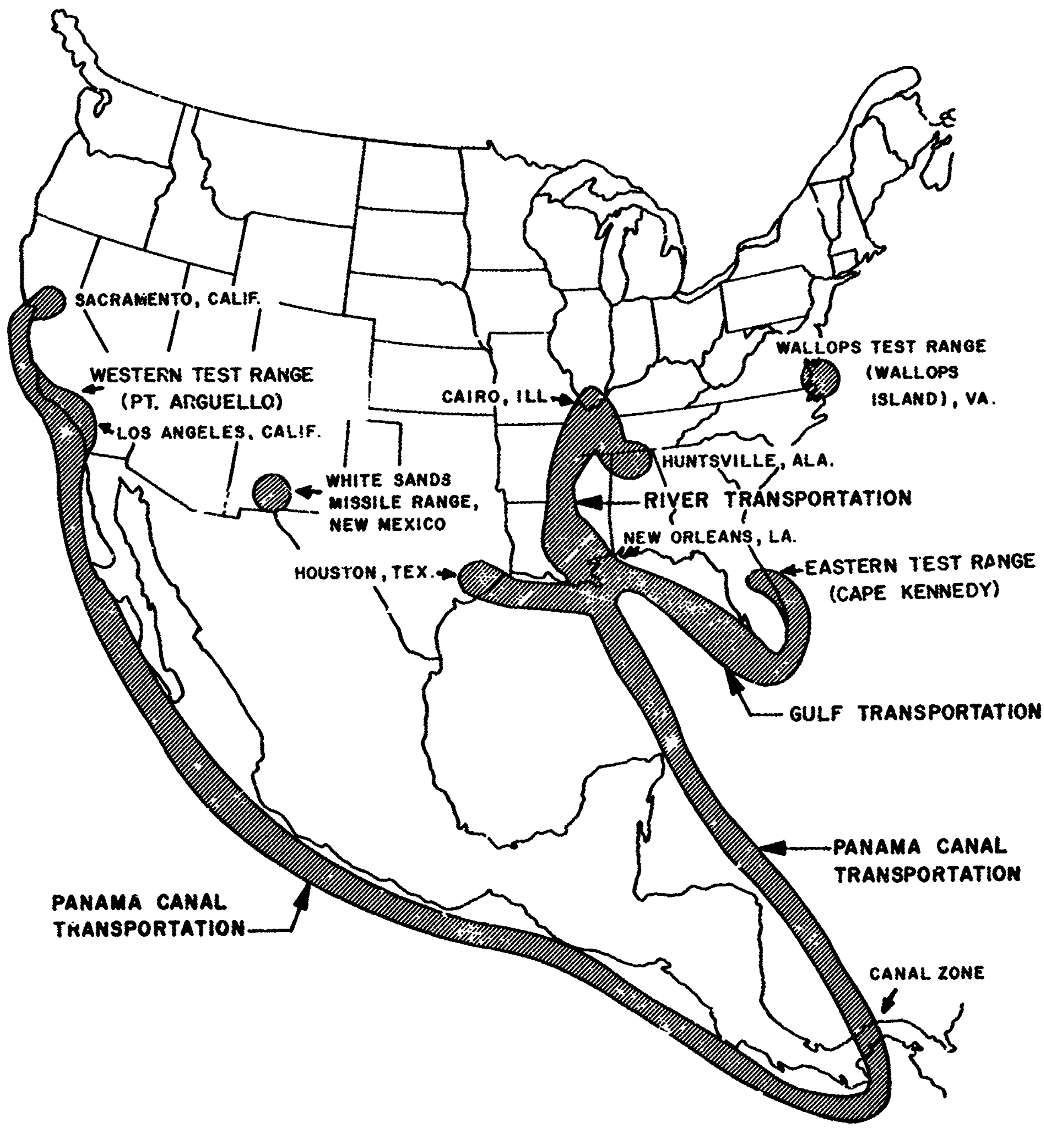

FIGURE 1.1 MAIN GEOGRAPHICAL AREAS COVERED IN DOCUMENT

1.3 Units of Conversion

Numerical values in this document are given in the International System of Units (Ref. 1.9, 1.10). The values in parentheses are equivalent U. S. Customary Units.* The metric and U. S. Customary Units employed in this report are those normally used for measuring and reporting atmospheric data.

By definition, the following fundamental conversion factors are exact (Ref. 1.9, 1.10, 1.11).

Type	U. S. Customary Units	Metric
Length	1 U. S. yard (yd)	0.9144 meter (m)
Mass	1 avoirdupois pound (lb)	453.59237 gram (g)
Time	1 second (s)	1 second (s)
Temperature	1 degree Rankine (°R)	1.8 degree Kelvin (°K)
Electric current	1 ampere (A)	1 ampere (A)
Light intensity	1 candela (cd)	1 candela (cd)

To aid in conversion of units given in this document, conversion factors based on the above fundamental conversion factors are given in Table 1.1. Geometric altitude as employed herein is with reference to mean sea level (MSL).

1.4 Definition of Percentiles

The values of the data given corresponding to the cumulative percentage frequencies are called percentiles. The relation between percentiles and probability is as follows: Given that the 90th percentile of the wind speed is, say, 60 m/s means that there is a probability of 0.90 that this value of the wind speed will not be exceeded, and there is probability of 0.10 that it will be exceeded for the sample of data from which the percentile was computed. Stated in another way: There is a 90 percent chance that the given wind speed of 60 m/s will not be exceeded or there is a 10 percent chance that it will be exceeded. If one considers the 10th and 90th percentiles for the wind speeds, it is clear that 80 percent of the wind speeds occur within the 10-90 percentiles range.

* English Units adopted for use by the United States of America.

TABLE 1.1 CONVERSION OF UNITS

	TYPE OF DATA	METRIC UNIT	METRIC ABBREVIATION	U.S. CUSTOMARY UNIT	U.S. CUSTOMARY ABBREVIATION	CONVERSION MULTIPLY	BY	TO GET
SOLAR RADIATION	Solar Intensity	langley (per minute)	ly (min^{-1})	watt per square foot	watt ft^{-2}	ly (min^{-1})	0.69733	kJ m^{-2}(s^{-1})
		gram-calorie per square centimeter (per minute)	g-cal cm^{-2}(min^{-1})	British Thermal Unit per square foot (per minute)	B.T.U. ft^{-2} (min^{-1})	kJ m^{-2} (s^{-1})	1.4340	ly (min^{-1})
		watt per square meter	watt m^{-2}			ly (min^{-1})	1.000*	g-cal cm^{-2}(min^{-1})
		kilojoule per square meter (per second)	kJ m^{-2}(s^{-1})			g-cal cm^{-2}(min^{-1})	1.000*	ly (min^{-1})
						watt m^{-2}	0.09290304*	watt ft^{-2}
						watt ft^{-2}	10.7639	watt m^{-2}
						g-cal cm^{-2}(min^{-1})	64.784	watt ft^{-2}
						g-cal cm^{-2}(min^{-1})	697.33	watt m^{-2}
						watt ft^{-2}	0.015436	g-cal cm^{-2}(min^{-1})
						watt m^{-2}	0.0014340	g-cal cm^{-2}(min^{-1})
						g-cal cm^{-2}(min^{-1})	3.6867	B.T.U. ft^{-2} (min^{-1})
						B.T.U. ft^{-2}(min^{-1})	0.27125	g-cal cm^{-2}(min^{-1})
	Solar Insolation	gram-calorie per square centimeter per minute	g-cal cm^{-2} min^{-1}	British Thermal Unit per square foot per hour	B.T.U. ft^{-2} hr^{-1}	g-cal cm^{-2} min^{-1}	221.20	B.T.U. ft^{-2} hr^{-1}
						B.T.U. ft^{-2} hr^{-1}	0.0045208	g-cal cm^{-2} min^{-1}
TEMPERATURE	Ambient Temperature	degree Celsius	°C	degree Fahrenheit	°F	°F - 32	0.5556	°C
		degree Kelvin	°K	degree Rankine	°R	°C	1.8*	°F - 32
						°R	1.00*	°F + 459.67
						°R - 459.67	1.00*	°F
						°K	1.00*	°C + 273.15
						°K - 273.15	1.00*	°C
	Temperature Change	degree Celsius	°C	degree Fahrenheit	°F	°C or °K	1.8*	temp. change °F or °R
		degree Kelvin	°K	degree Rankine	°R	°F or °R	0.5556	temp. change °C or °K

* Defined exact conversion factor

TABLE 1.1 CONVERSION OF UNITS (CONT.)

	TYPE OF DATA	METRIC UNIT	METRIC ABBREVIATION	U.S. CUSTOMARY UNIT	U.S. CUSTOMARY ABBREVIATION	CONVERSION MULTIPLY	CONVERSION BY	CONVERSION TO GET
DENSITY	Water Vapor Vapor Concentration (Absolute Humidity)	gram per cubic meter	$g\ m^{-3}$	grain per cubic foot	$gr\ ft^{-3}$	$g\ m^{-3}$	0.43700	$gr\ ft^{-3}$
		gram per cubic centimeter	$g\ cm^{-3}$			$gr\ ft^{-3}$	2.2883	$g\ m^{-3}$
						$g\ m^{-3}$	10^{-6}*	$g\ cm^{-3}$
						$g\ cm^{-3}$	4.370×10^{5}	$gr\ ft^{-3}$
						$gr\ ft^{-3}$	2.288×10^{-6}	$g\ cm^{-3}$
	Air, Dust, and Hail	gram per cubic centimeter	$g\ cm^{-3}$	pound per cubic foot	$lb\ ft^{-3}$	$g\ cm^{-3}$	62.43	$lb\ ft^{-3}$
						$lb\ ft^{-3}$	1.6018×10^{-2}	$g\ cm^{-3}$
PRECIPITATION	Snow Unit Depth Force	kilogram per square meter per centimeter (of depth)	$kg\ m^{-2}\ cm^{-2}$	pound per square foot per inch (of depth)	$lb\ ft^{-2}\ in.^{-1}$	$kg\ m^{-2}\ cm^{-1}$	0.5202	$lb\ ft^{-2}\ in.^{-1}$
						$lb\ ft^{-2}\ in.^{-1}$	1.922	$kg\ m^{-2}\ cm^{-1}$
	Snow Storm Total Force	kilogram per square meter	$kg\ m^{-2}$	pound per square foot	$lb\ ft^{-2}$	$kg\ m^{-2}$	0.2048	$lb\ ft^{-2}$
						$lb\ ft^{-2}$	4.882	$kg\ m^{-2}$
	Depth	centimeter	cm	inch	in.	cm	0.3937	in.
						in.	2.54*	cm
WIND	Wind Speed	meter per second	$m\ s^{-1}$	mile per hour	mph	$m\ s^{-1}$	2.2369	mph
				knots	knots	mph	0.44704*	$m\ s^{-1}$
				feet per second	$ft\ s^{-1}$	$m\ s^{-1}$	1.9438	knots
						knots	0.51444	$m\ s^{-1}$
						mph	0.868976	knots
						knots	1.15078	mph
						$m\ s^{-1}$	3.2808	$ft\ s^{-1}$
						$ft\ s^{-1}$	0.3048*	$m\ s^{-1}$

*Defined exact conversion factor

T’ 1.1 CONVERSION OF UNITS (CONT.)

TYPE OF DATA		METRIC		U.S. CUSTOMARY		CONVERSION		
		UNIT	ABBREVIATION	UNIT	ABBREVIATION	MULTIPLY	BY	TO GET
PRESSURE	Atmospheric	newton per square meter	newton m^{-2}	pound force per square inch	lbf $in.^{-2}$	mb	10^{-3*}	bar
						bar	10^{3*}	mb
		millimeter of Mercury	mmHg	inch of Mercury	in.Hg	newton m^{-2}	10^{-2*}	mb
						newton m^{-2}	$1.4504X10^{-4}$	lbf $in.^{-2}$
						lbf $in.^{-2}$	$6.8948X10^{3}$	newton m^{-2}
		bar	bar			mb	$1.4504X10^{-2}$	lbf $in.^{-2}$
		millibar	mb			lbf $in.^{-2}$	68.948	mb
		dyne per square centimeter (microbar)	dyne cm^{-2}			mb	10^{3*}	dyne cm^{-2}
						dyne cm^{-2}	10^{-3*}	mb
		kilogram force per square meter	kgf m^{-2}			lbf $in.^{-2}$	$6.8948X10^{4}$	dyne cm^{-2}
						dyne cm^{-2}	$1.4504X10^{-5}$	lbf $in.^{-2}$
						mb	10.1972	kgf m^{-2}
						kgf m^{-2}	0.0980665	mb
						lbf $in.^{-2}$	703.0696	kgf m^{-2}
						kgf m^{-2}	0.0014223	lbf $in.^{-2}$
						mb	$2.9530X10^{-2}$	in.Hg (32° F)
						mb	0.75006	mmHg (0° C)
						in.Hg(32° F)	25.40^{*}	mmHg (0° C)
						mmHg(0° C)	1.33322	mb
						in.Hg(32° F)	33.8639	mb

* Defined exact conversion factor

TABLE 1.1 CONVERSION OF UNITS (CONT.)

TYPE OF DATA		METRIC		U.S. CUSTOMARY		CONVERSION		
		UNIT	ABBREVIATION	UNIT	ABBREVIATION	MULTIPLY	BY	TO GET
DISTANCE	Length	meter	m	feet	ft	m	3.2808	ft
		micron	μ	inch	in.	ft	0.3048*	m
		Ångstrom unit	Å			in.	$2.54 \times 10^{+4}$*	μ
						in.	$2.54 \times 10^{+8}$*	Å
						m	10^{+6}*	μ
						m	10^{+10}*	Å
						μ	10^{-6}*	m
						μ	3.937×10^{-5}	in.
						Å	10^{-10}*	m
						Å	3.937×10^{-9}	in.
MASS	Weight	gram	g	grain	gr	lb	0.45359237*	kg
		kilogram	kg	pound	lb	lb	453.59237*	g
						kg	2.20462	lb
						g	15.4324	gr
						gr	0.06480	g

* Defined exact conversion factor

1.5 Geographical Areas Involved in Vehicle Design

Many geographical areas are involved in the fabrication, transportation, testing, and launch of a space vehicle, since the various segments are fabricated in different areas. Figure 1.2 shows the major locations pertinent to the fabrication, and testing of the Saturn V vehicle. Similar information is available in appropriate data books concerning other space vehicles. By the use of information such as that given in Figure 1.2, data from this guideline document can be readily extracted for use as design criteria. Figure 1.2 is only given as an example and is not intended for planning use.

SECONDARY FUNCTIONAL AREA	FUNCTION	ASSEMBLY	IN-PLANT CHECKOUT	ACCEPTANCE TEST	REFURBISH AND CHECKOUT	PREASSEMBLY CHECKOUT
INSTRUMENT UNIT	FACILITY	IBM HUNTSVILLE FACILITY	IBM HUNTSVILLE FACILITY	N A	N A	KSC
S-IV B STAGE		DAC HUNTINGTON BEACH FACILITY	DAC SACRAMENTO FACILITY	DAC SACRAMENTO FACILITY	DAC SACRAMENTO FACILITY	KSC
J-2 ENGINE		ROCKETDYNE CANOGA PARK FACILITY	NAA ROCKETDYNE CANOGA PARK FACILITY	ROCKETDYNE SANTA SUSANNA FACILITY	ROCKETDYNE SANTA SUSANNA FACILITY	KSC
S-II STAGE		SPACE & INFORMATION DIVISION SEAL BEACH FACILITY	SPACE & INFORMATION DIVISION SANTA SUSANNA FACILITY	MISSISSIPPI TEST OPERATIONS	MISSISSIPPI TEST OPERATIONS	KSC
S-IC STAGE		MSFC (S-IC-1 and -2) TBC MICHOUD (S-IC-3 and subsequent)	MSFC (S-IC-1 and -2) TBC MICHOUD (S-IC-3 and subsequent)	MSFC (S-IC-1 and -2) TBC MTO (S-IC-3 and subsequent)	MSFC (S-IC-1 and -2) TBC MTO (S-IC-3 and subsequent)	KSC
F-1 ENGINE		ROCKETDYNE CANOGA PARK FACILITY	ROCKETDYNE CANOGA PARK FACILITY	ROCKETDYNE EDWARDS AIR FORCE BASE FACILITY	ROCKETDYNE EDWARDS AIR FORCE BASE FACILITY	KSC

LEGEND

MSFC - MARSHALL SPACE FLIGHT CENTER
KSC - KENNEDY SPACE CENTER
MTO - MISSISSIPPI TEST OPERATIONS
IBM - INTERNATIONAL BUSINESS MACHINES
DAC - DOUGLAS AIRCRAFT COMPANY
TBC - THE BOEING COMPANY
N A - NOT APPLICABLE

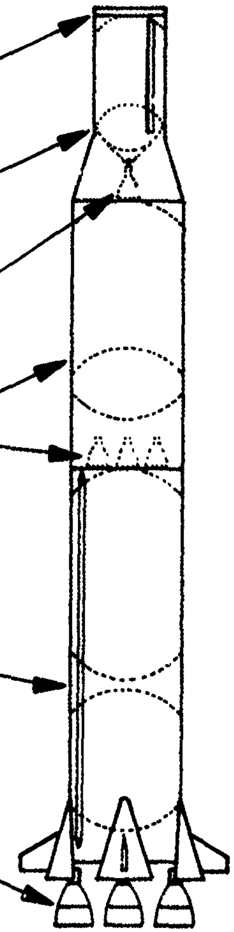

FIGURE 1.2 EXAMPLE OF LOCATIONS PERTINENT TO THE FABRICATION AND TESTING OF COMPONENTS OF THE SATURN V VEHICLE

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1.5 Cole, A. E.; and Kantor, A. J.: "Air Force Interim Supplemental Atmospheres to 90 Kilometers." Air Force Surveys in Geophysics No. 153, 1963.

1.6 IRIG Document No. 104-63, Range Reference Atmosphere Documents published by Secretariat, Range Commander's Council, White Sands Missile Range, New Mexico.

a. The following reference atmospheres have been published:

(1) Atlantic Missile Range Reference Atmosphere for Cape Kennedy, Florida (Part I), 1963.

(2) White Sands Missile Range Reference Atmosphere (Part I), 1964.

(3) Fort Churchill Missile Range Reference Atmosphere for Fort Churchill, Canada (Part I), 1964.

(4) Pacific Missile Range Reference Atmosphere for Eniwetok, Marshall Islands (Part I), 1964.

(5) Fort Greely Missile Range Reference Atmosphere (Part I), 1964.

(6) Eglin Gulf Test Range Reference Atmosphere for Eglin, AFB, Florida (Part I), 1965.

(7) Pacific Missile Range Reference Atmosphere for Point Arguello, California (Part I), 1965.

(8) Wallops Island Test Range Reference Atmosphere (Part I), 1965.

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SECTION II. THERMAL ENVIRONMENT

By

Glenn E. Daniels

2.1 Definitions.

Absorption bands are those portions of the solar (or other continuous) spectrum which have lesser intensity because of absorption by gaseous elements or molecules. In general, elements give sharp lines, but molecules such as water vapor or carbon dioxide in the infrared, give broad diffuse bands.

Air mass is the amount of atmosphere that the solar radiation passes through where one air mass represents the atmosphere when the sun is in the zenith. In this document the value for one air mass used is represented by an air mass without clouds that gives a solar intensity of 1.64 g-cal cm^{-2} on a horizontal surface.

Air temperature (surface) is the free or ambient air temperature measured, under standard conditions of height, ventilation, and radiation shielding. The air temperature is normally measured with liquid-in-glass thermometers in a louvered wooden shelter, painted white inside and outside, with the base of the shelter normally 1.22 m (four feet) above a close-cropped grass surface (Ref. 2.1, page 59). Unless an exception is stated, surface air temperatures given in this report are temperatures measured under these standard conditions.

Astronomical unit is a unit of length defined as equal to the mean distance between the Earth and Sun.

Atmospheric transmittance is the ratio between the intensity of the extraterrestrial solar radiation and intensity of the solar radiation after passing through one air mass of atmosphere. The tabular values of atmospheric transmittance given in Table 2.1 are based on a specific one air mass as defined in the text.

Black body is an object which absorbs incident radiation in all wave lengths.

Diffuse sky radiation is the radiation emitted by the sky from scattering of solar radiation, by molecules and dust, and by reflectance from clouds and fog. It is the radiation which is measured on a surface after the direct solar radiation is subtracted from the total.

Direct solar radiation is the radiation received on a surface directly from the sun, and does not include diffuse sky radiation.

Emittance is the ratio of the energy emitted by a body to the energy which would be emitted by a black body at the same temperature. A black body has an emittance of 1.0.

Extraterrestrial solar radiation is that solar radiation received outside the Earth's atmosphere at one astronomical unit from the Sun.

Fraunhofer lines are the absorption bands in the solar spectrum.

Horizontal solar radiation is that solar radiation measured on a horizontal surface.

Irradiation is often used to mean solar radiation received by a surface.

Normal incident solar radiation is the radiation received on a surface, normal to the direction of the sun, direct from the sun, and does not include diffuse sky radiation.

Radiation temperature is the temperature of a radiating body (assumed as black) determined by Wien's displacement law, expressed as

$$T_R = \frac{w}{\lambda max} \qquad \text{Eq. (2.1)}$$

where

T_R = Radiation temperature (°K)

w = Wien's displacement constant (0.2989 cm °K)

λmax = The wavelength corresponding to the maximum energy of radiation (cm).

Sky radiation temperature is the average radiation temperature of the sky when it is assumed as a black body. Sky radiation is the radiation to and through the atmosphere from outer space. While this radiation is normally termed nocturnal radiation, it takes place under clear skies even during daylight hours.

Solar radiation in this document will be defined as the radiant energy from the sun between 2200 Ångstroms and 70,000 Ångstroms (See para. 2.2.2).

Surface temperature is the temperature which a given surface will have when exposed to air temperature and radiation within the approximate wavelength interval of 0.15 to 20.0 microns. Extremes of surface temperatures will be dependent on the emittance of the surface, angle between the surface and the radiation source (such as the sun or sky), the radiation temperature of the source, and the subtended angle of the source. The extreme value of temperature which a surface will reach when exposed to daytime (solar) or nighttime (night sky) radiation with no wind (calm) can be found as follows:

$$T_S = T_A + E\,(\Delta T_{BS}) \qquad \text{Eq. (2.2)}$$

where

T_S = Surface temperature (°K)

T_A = Air temperature (°K)

E = Emittance of surface

ΔT_{BS} = Increase in black body temperature (°K) from daytime solar radiation (used as plus) or decrease in black body temperature (°K) from nighttime sky radiation (used as minus) and is found from

$$\Delta T_{BS} = \left(\frac{I_{TS}}{\sigma}\right)^{\frac{1}{4}} - T_A. \qquad \text{Eq. (2.3)}$$

Extreme values of ΔT_{BS} can be found from Figure 2.3A or Table 2.9 where

I_{TS} = Total radiation (solar for day) (sky for night) received at surface. These values can be extremes from Tables 2.2, 2.3, or 2.5 from this report.

σ = Stefans-Boltzman constant

= 8.17×10^{-11} g-cal min^{-1} (deg K)$^{-4}$.

The term $\left(\frac{I_{TS}}{\sigma}\right)^{\frac{1}{4}}$ is equal to the extreme black body surface temperature.

If a correction for wind speed is desired, Eq. (2.2) can be used as follows:

$$T_S = T_A + E(\Delta T_{BS}) \frac{Wc}{100} \qquad \text{Eq. (2.2A)}$$

where

Wc = correction for wind speed in percent from Figure 2.3B.

Total solar radiation is the direct and diffuse sky radiation received by a surface.

Transmittance (see "Atmospheric transmittance").

2.2 Solar Electromagnetic Spectrum.

2.2.1 Introduction. The sun is emitting energy in the electromagnetic spectrum between 0.0001 Ångstroms and 1,000,000 Ångstroms. This radiation ranges from cosmic rays through the very long radio waves.

2.2.2 Solar Radiation Energy Distribution.

Of the total electromagnetic spectrum of the sun, only the radiant energy from that portion of the spectrum between 2200 Ångstroms and 70,000 Ångstroms (the light spectrum) will be considered in this document since it contains 99.8 percent of the total electromagnetic energy. The spectral distribution of this region closely resembles the emission of a gray body radiating at 6000° C. This is the spectral region which results in heating or cooling of an object.

The distribution of the solar radiation outside the atmosphere is a continuous spectrum with many narrow absorption bands caused by the elements and molecules in the colder solar atmosphere. These absorption bands are the Fraunhofer lines, whose widths are usually very small (less than 1 Ångstrom in most cases).

Additional information on the entire solar spectrum may be found in NASA TM X-53018, "Space Radiation: A Compilation and Discussion" (Ref. 2.2).

The earth's atmosphere also absorbs a part of the solar radiation such that the major portion of the solar radiation reaching the earth surface is between

about 3500 Ångstroms and 40,000 Ångstroms. The distribution of the energy in this region of the spectrum outside the atmosphere (extraterrestrial) is as follows:

Region	Distribution * Percent	Solar Intensity ** g-cal cm^{-2}
Ultra Violet below 3800 Å	6.4	0.128
3800 Å to 7500 Å	46.8	0.936
Infrared above 7500 Å	46.8	0.936

The first detailed information published for use of engineers on the distribution of solar radiation energy (solar irradiation) with wavelength was that by Parry Moon in 1940 (Ref. 2.5). This data were generally based on theoretical curves, but are still used as the basic solar radiation in design by many engineers.

The information on solar radiation intensities with wavelength, outside the Earth's atmosphere, at the mean distance of the Earth from the Sun (one Astronomical Unit) must be extrapolated from measurements made at the earth's surface. The current procedure is to reduce the data to that equivalent to one air mass (Sun in the zenith) when no clouds exist and then use an atmospheric transmittance curve based on measured and theoretical absorption values of ozone, water vapor (or precipitable water), dust and atmospheric molecules to extrapolate to zero air mass. Moon computed his data by assuming a 6000° C gray body and assuming an atmospheric transmission curve for computing the curves for various air masses. The total area under the curve for solar intensities outside the Earth's atmosphere (zero air mass) must equal the solar constant.

More recent measurements of solar radiation by the National Bureau of Standards (NBS) (Refs. 2.6, 2.7), and the National Geographic Society (Ref. 2.8) in conjunction with the revision of the value of the Solar Constant from 1.896 g-cal cm^{-2}, used by Moon (Ref. 2.5), to 2.00 g-cal cm^{-2} (1395 watt m^{-2}),

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* Mean of Johnson (Ref. 2.3) and Nicolet (Ref. 2.4).

** Based on Solar Constant of 2.00 g-cal cm^{-2}

now accepted as the correct value, have resulted in revised values for solar radiation intensities outside the earth's atmosphere and within the earth's atmosphere.

2.2.3 Intensity Distribution.

In Table 2.1, data are given of the solar radiation intensity distribution with wavelength. The main purpose of the table is to provide guidance on the distribution of solar radiation at the earth's surface; therefore, the intensity of the solar radiation, after penetration of one air mass for a day with maximum solar radiation at the earth's surface, is given by a constant (atmospheric transmittance) to use in computation of the solar radiation intensity for other thicknesses of air mass. These data are based on two sets of measurements made at Sacramento Peak by the National Bureau of Standards in 1953 and 1955 (Ref. 2.6 and 2.7) and Moon's (Ref. 2.5) data for wavelengths above 5450 Ångstroms. Because the NBS and Moon's data were based on an average air mass* without clouds, adjustment of the atmospheric transmission was made by considering less ozone and water vapor than that occurring on a normal day. The adjustment was made such that the area under the curve for one air mass total 1.64 g-cal cm^{-2} (82 percent of the Solar Constant); i.e., the extreme value for total normal incident solar radiation for June at the Eastern Test Range (See Table 2.3). Actual measurements of the intensity of the solar spectrum in the infrared relative to the total incoming solar radiation are almost nonexistent because of the difficulty of calibrating a reference standard (See Ref. 2.9 and 2.10). The data presented in Table 2.1 for one air mass should represent closely the actual data which might have been measured on the day when the extreme value occurred because the adjustment of the data was restricted in making the area under the curve fit the extreme value measured.

2.2.4 Atmospheric Transmittance.

The atmospheric transmittance constant can be used in the following equation for computations of Intensities for other number of air masses.

$$I_N = I_o (M^N) \qquad \text{Eq. (2.4)}$$

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* This air mass is assumed to contain no clouds, 0.23 cm of ozone, 0.20 cm of water vapor and have standard sea level pressure (1013.25 millibars).

Table 2.1 Solar Radiation Distribution with Wavelength based on a Solar Constant of 2.00 g cal cm^{-2} (1395 watt m^{-2})

WAVE-LENGTH	EXTRATERRESTRIAL SOLAR RADIATION (I_E) NBS (Refs. 2.6 and 2.7)				SOLAR RADIATION FOR ONE (1.00) AIR MASS ($I_{1.00}$) NBS (Refs. 2.6 and 2.7)				ATMOSPHERIC TRANSMITTANCE	EXTRATERRESTRIAL SOLAR RADIATION MEAN OF JOHNSON (Ref. 2.3) and NICOLET (Ref. 2.4)			
λ	per 100 Angstroms				per 100 Angstroms				RATIO (M)	per 100 Angstroms			
	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		$I_E / I_{1.00}$	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY	
Angstroms (Å)	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	Unitless	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}
2100	Use Mean of Johnson and Nicolet for this section from 2100Å to 2900Å.				0	0	0	0	∞	0	0	0	0
2200					0	0	0	0	∞	0.015	0.008	0.00030	0.209
2300					0	0	0	0	∞	0.035	0.032	0.00070	0.488
2400					0	0	0	0	∞	0.035	0.068	0.00070	0.488
2500					0	0	0	0	∞	0.045	0.108	0.00090	0.628
2600					0	0	0	0	∞	0. 95	0.178	0.00190	1.33
2700					0	0	0	0	∞	0.150	0.300	0.00300	2.09
2800					0	0	0	0	∞	0.140	0.445	0.00280	1.95
2900		0.672			0	0	0	0	∞	0.315	0.672	0.00630	4.39
2990	0.36		0.00715	4.99	0.009		0.00018	0.125	40				
2995	0.43		0.00865	6.04	0.022		0.00043	0.302	20				
3000	0.48	1.014	0.00967	6.75	0.048	0.007	0.00097	0.675	10	0.370	1.014	0.00740	5.16
3025	0.39		0.00778	5.43	0.082		0.00163	1.14	4.75				
3040	0.52		0.01030	7.19	0.128		0.00255	1.78	4.04				
3050	0.50		0.00994	6.94	0.135		0.00271	1.89	3.68				
3060	0.50		0.01009	7.04	0.148		0.00297	2.07	3.40				
3092	0.62		0.01241	8.66	0.220		0.00440	3.07	2.82				
3100	0.51	1.527	0.01023	7.14	0.189	0.141	0.00377	2.63	2.72	0.495	1.447	0.00991	6.91
3120	0.74		0.01482	10.34	0.297		0.00594	4.14	2.50				
3149	0.69		0.01381	9.64	0.310		0.00619	4.32	2.23				
3150	0.71		0.01414	9.86	0.318		0.00637	4.44	2.22				
3158	0.71		0.01419	9.90	0.329		0.00658	4.59	2.18				
3165	0.60		0.01211	8.45	0.283		0.00566	3.95	2.14				
3179	0.81		0.01628	11.36	0.391		0.007 3	5.46	2.08				
3185	0.71		0.01410	9.84	0.344		0.00688	4.80	2.05				

Table 2.1 Solar Radiation Distribution with Wavelength based on a Solar Constant of 2.00 g cal cm^{-2} (1395 watt m^{-2}) (Cont'd)

WAVE-LENGTH	EXTRATERRESTRIAL SOLAR RADIATION (I_E) NBS (Refs. 2.6 and 2.7)				SOLAR RADIATION FOR ONE (1.00) AIR MASS ($I_{1.00}$) NBS (Refs. 2.6 and 2.7)				ATMOSPHERIC TRANSMITTANCE	EXTRATERRESTRIAL SOLAR RADIATION MEAN OF JOHNSON (Ref. 2.3) and NICOLET (Ref. 2.4)			
λ	per 100 Angstroms				per 100 Angstroms				RATIO (M)	per 100 Angstroms			
	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		$I_E / I_{1.00}$	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY	
Angstroms (Å)	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	Unitless	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}
3200	0.75	2.224	0.01491	10.40	0.376	0.451	0.00753	5.25	1.98	0.565	1.977	0.01140	7.95
3211	0.82		0.01631	11.38	0.421		0.00842	5.87	1.94				
3217	0.74		0.01485	10.36	0.389		0.00777	5.42	1.91				
3228	0.71		0.01416	9.88	0.378		0.00757	5.28	1.87				
3235	0.65		0.01290	9.00	0.351		0.00701	4.89	1.84				
3250	0.72		0.01433	10.00	0.403		0.00806	5.62	1.78				
3255	0.75		0.01508	10.52	0.426		0.00852	5.94	1.77				
3275	0.96		0.01921	13.40	0.565		0.01130	7.88	1.70				
3285	0.92		0.01837	12.82	0.551		0.01101	7.68	1.67				
3300	1.03	3.035	0.02064	14.40	0.633	0.908	0.01266	8.83	1.63	0.730	2.624	0.01460	10.18
3303	1.04		0.02081	14.52	0.642		0.01285	8.96	1.62				
3315	0.93		0.01852	12.92	0.583		0.01166	8.13	1.59				
3329	0.92		0.01835	12.80	0.589		0.01177	8.21	1.56				
3336	0.89		0.01782	12.43	0.575		0.01150	8.02	1.55				
3350	0.93		0.01863	13.00	0.613		0.01226	8.55	1.52				
3353	0.93		0.01852	12.92	0.609		0.01219	8.50	1.52				
3370	0.78		0.01559	10.88	0.523		0.01047	7.30	1.49				
3400	0.91	3.931	0.01827	12.75	0.630	1.494	0.01260	8.79	1.45	0.715	3.347	0.01430	9.97
3408	0.94		0.01872	13.06	0.650		0.01301	9.07	1.44				
3417	0.89		0.01784	12.45	0.624		0.01249	8.71	1.43				
3435	0.92		0.01832	12.78	0.649		0.01299	9.06	1.41				
3450	0.77		0.01534	10.70	0.560		0.01120	7.81	1.37				
3500	0.87	4.787	0.01746	12.18	0.642	2.108	0.01285	8.96	1.36	0.755	4.082	0.01510	10.53
3515	0.93		0.01855	12.94	0.687		0.01375	9.59	1.35				
3526	0.87		0.01734	12.10	0.642		0.01285	8.96	1.35				

Table 2.1 Solar Radiation Distribution with Wavelength based on a Solar Constant of 2.00 g cal cm^{-2} (1395 watt m^{-2})(Cont'd)

WAVE-LENGTH	EXTRATERRESTRIAL SOLAR RADIATION (I_E) NBS (Refs. 2.6 and 2.7)				SOLAR RADIATION FOR ONE (1.00) AIR MASS ($I_{1.00}$) NBS (Refs. 2.6 and 2.7)				ATMOSPHERIC TRANSMITTANCE	EXTRATERRESTRIAL SOLAR RADIATION MEAN OF JOHNSON (Ref. 2.3) and NICOLET (Ref. 2.4)			
	per 100 Angstroms				per 100 Angstroms				RATIO(M)	per 100 Angstroms			
λ	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		$I_E / I_{1.00}$	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY	
Angstroms (Å)	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	Unitless	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}
3550	0.97		0.01949	13.60	0.728		0.01456	10.15	1.34				
3551	0.98		0.01968	13.73	0.735		0.01470	10.25	1.34				
3580	0.71		0.01428	9.96	0.541		0.01083	7.55	1.32				
3600	0.91	5.659	0.01813	12.65	0.687	2.751	0.01374	9.58	1.32	0.755	4.837	0.01510	10.53
3610	0.85		0.01694	11.82	0.647		0.01293	9.02	1.31				
3637	0.91		0.01827	12.75	0.703		0.01407	9.81	1.30				
3650	0.99		0.01971	13.75	0.764		0.01529	10.66	1.29				
3667	1.07		0.02134	14.89	0.827		0.01655	11.54	1.29				
3682	1.01		0.02021	14.10	0.790		0.01580	11.02	1.28				
3700	1.02	6.580	0.02047	14.28	0.800	3.495	0.01600	11.16	1.28	0.815	5.622	0.01630	11.37
3705	1.03		0.02055	14.34	0.809		0.01619	11.29	1.27				
3742	0.81		0.01621	11.31	0.644		0.01288	8.98	1.26				
3750	0.84		0.01671	11.66	0.663		0.01326	9.25	1.26				
3788	1.11		0.02219	15.48	0.887		0.01775	12.38	1.25				
3800	1.04	7.538	0.02078	14.50	0.838	4.254	0.01676	11.69	1.24	0.775	6.417	0.01550	10.81
3804	0.99		0.01989	13.88	0.802		0.01605	11.19	1.24				
3845	0.66		0.01329	9.27	0.540		0.01081	7.54	1.23				
3850	0.68		0.01350	9.42	0.553		0.01107	7.72	1.22				
3874	0.83		0.01668	11.64	0.690		0.01380	9.62	1.21				
3900	1.02	8.372	0.02045	14.27	0.852	4.939	0.01705	11.89	1.20	0.760	7.148	0.01520	10.60
3912	1.06		0.02113	14.74	0.880		0.01761	12.28	1.20				
3937	0.69		0.01385	9.66	0.582		0.01164	8.12	1.19				
3950	0.80		0.01591	11.10	0.669		0.01338	9.33	1.19				
3960	0.94		0.01879	13.11	0.790		0.01580	11.02	1.19				
3970	0.84		0.01684	11.75	0.714		0.01428	9.96	1.18				

Table 2.1 Solar Radiation Distribution with Wavelength based on a Solar Constant of 2.00 g cal cm^{-2} (1395 watt m^{-2}) (Cont'd)

WAVE-LENGTH	EXTRATERRESTRIAL SOLAR RADIATION (I_E) NBS (Refs. 2.6 and 2.7)				SOLAR RADIATION FOR ONE (1.00) AIR MASS ($I_{1.00}$) NBS (Refs. 2.6 and 2.7)				ATMOSPHERIC TRANSMITTANCE	EXTRATERRESTRIAL SOLAR RADIATION MEAN OF JOHNSON (Ref. 2.3) and NICOLET (Ref. 2.4)			
	per 100 Angstroms				per 100 Angstroms				RATIO (M)	per 100 Angstroms			
λ	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		$I_E / I_{1.00}$	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY	
Angstroms (Å)	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	Unitless	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}
4000	1.09	9.278	0.02177	15.19	0.930	5.702	0,01861	12.98	1.17	1.110	8.120	0.02220	15.48
4034	1.45		0.02905	20.26	1.25		0.02505	17.47	1.16				
4050	1.40		0.02808	19.58	1.21		0.02421	16.88	1.16				
4062	1.37		0.02745	19.14	1.18		0.02366	16.50	1.16				
4100	1.37	10.624	0.02745	19.14	1.19	6.863	0.02386	16.[illegible]	1.15	1.330	9.340	0.02660	18.55
4101	1.37		0.02745	19.14	1.19		0.02386	16.64	1.15				
4150	1.40		0.02802	19.54	1.24		0.02479	17.29	1.13				
4168	1.42		0.02846	19.85	1.27		0.02532	17.66	1.13				
4200	1.41	12.023	0.02822	19.68	1.26	8.101	0.02520	17.57	1.12	1.325	10.667	0.02650	18.48
4208	1.41		0.02819	19.66	1.26		0.02517	17.55	1.12				
4237	1.36		0.02713	18.92	1.22		0.02444	17.04	1.11				
4250	1.28		0.02553	17.80	1.15		0.02300	16.04	1.11				
4276	1.14		0.02289	15.96	1.03		0.02062	14.38	1.11				
4300	1.20	13.304	0.02409	16.80	1.09	9.253	0.02171	15.14	1.11	1.235	11.947	0.02471	17.23
4322	1.29		0.02584	18.02	1.16		0.02327	16.23	1.11				
4350	1.33		0.02667	18.60	1.20		0.02403	16.76	1.11				
4371	1.37		0.02746	19.15	1.24		0.02474	17.25	1.11				
4400	1.47	14.640	0.02940	20.50	1.34	10.461	0.02673	18.64	1.10	1.415	13.272	0.02831	19.74
4408	1.50		0.02996	20.89	1.36		0.02723	18.99	1.10				
4450	1.56		0.03126	21.80	1.42		0.02842	19.82	1.10				
4489	1.58		0.03163	22.06	1.44		0.02875	20.05	1.10				
4500	1.57	16.187	0.03137	21.88	1.43	11.686	0.02852	19.89	1.10	1.550	14.754	0.03100	21.62
4557	1.58		0.03153	21.99	1.43		0.02867	19.99	1.10				
4600	1.54	17.756	0.03076	21.45	1.40	13.292	0.02796	19.50	1.10	1.555	16.307	0.03110	21.69
4665	1.47		0.02948	20.56	1.34		0.02680	18.69	1.10				

Table 2.1 Solar Radiation Distribution with Wavelength based on a Solar Constant of 2.00 g cal cm^{-2} (1395 watt m^{-2})(Cont'd)

WAVE-LENGTH	EXTRATERRESTRIAL SOLAR RADIATION (I_E) NBS (Refs. 2.6 and 2.7)				SOLAR RADIATION FOR ONE (1.00) AIR MASS ($I_{1.00}$) NBS (Refs. 2.6 and 2.7)				ATMOSPHERIC TRANSMITTANCE	EXTRATERRESTRIAL SOLAR RADIATION MEAN OF JOHNSON (Ref. 2.3) and NICOLET (Ref. 2.4)			
	per 100 Angstroms				per 100 Angstroms				RATIO (M)	per 100 Angstroms			
λ	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		$I_E / I_{1.00}$	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY	
Angstroms (Å)	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	Unitless	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}
4700	1.47	19.249	0.02940	20.50	1.35	14.653	0.02697	18.81	1.09	1.565	17.867	0.03130	21.83
4800	1.51	20.739	0.03011	21.00	1.38	16.018	0.02763	19.27	1.09	1.560	19.430	0.03120	21.76
4820	1.53		0.03052	21.28	1.40		0.02799	19.52	1.09				
4870	1.38		0.02763	19.27	1.27		0.02535	17.68	1.09				
4900	1.42	22.190	0.02832	19.75	1.30	17.349	0.02598	18.12	1.09	1.445	20.932	0.02890	20.16
4970	1.49		0.02986	20.82	1.37		0.02743	19.13	1.09				
5000	1.46	23.659	0.02922	20.38	1.34	18.690	0.02682	18.70	1.09	1.460	22.384	0.02920	20.36
5090	1.50		0.03006	20.96	1.38		0.02758	19.23	1.09				
5100	1.49	25.141	0.02986	20.82	1.37	20.052	0.02739	19.10	1.09	1.455	23.841	0.02910	20.29
5190	1.42		0.02844	19.83	1.30		0.02608	18.19	1.09				
5200	1.42	26.564	0.02836	19.78	1.30	21.383	0.02603	18.15	1.09	1.370	25.254	0.02740	19.11
5225	1.47		0.02937	20.48	1.35		0.02694	18.79	1.09				
5265	1.49		0.02980	20.78	1.37		0.02733	19.06	1.09				
5275	1.53		0.03069	21.40	1.41		0.02815	19.63	1.09				
5300	1.52	28.050	0.03036	21.17	1.39	22.748	0.02785	19.42	1.09	1.430	26.654	0.02861	19.95
5350	1.49		0.02971	20.72	1.36		0.02726	19.01	1.09				
5400		29.540				24.108				1.440	28.088	0.02879	20.08
5450	1.50		0.02991	20.86	1.37		0.02745	19.14	1.09				
5500		31.040				25.478				1.395	29.506	0.02791	19.46
5550	1.48		0.02956	20.61	1.36		0.02712	18.91	1.09				
5600		32.520				26.838				1.404	30.906	0.02809	19.59
5650	1.46		0.02918	20.35	1.34		0.02677	18.67	1.09				
5700		33.980				28.178				1.385	32.300	0.03770	19.32
5750	1.44		0.02872	20.03	1.32		0.02636	18.38	1.09				
5800		35.420				29.498				1.385	33.685	0.02770	19.32

Table 2.1 Solar Radiation Distribution with Wavelength based on a Solar Constant of 2.00 g cal cm^{-2} (1395 watt m^{-2})(Cont'd)

WAVE-LENGTH	EXTRATERRESTRIAL SOLAR RADIATION (I_E) NBS (Refs. 2.6 and 2.7)				SOLAR RADIATION FOR ONE (1.00) AIR MASS ($I_{1.00}$) NBS (Refs. 2.6 and 2.7)				ATMOSPHERIC TRANSMITTANCE	EXTRATERRESTRIAL SOLAR RADIATION MEAN OF JOHNSON (Ref. 2.3) and NICOLET (Ref. 2.4)			
λ	per 100 Angstroms				per 100 Angstroms				RATIO(M)	per 100 Angstroms			
	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		$I_E / I_{1.00}$	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY	
Angstroms (Å)	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	Unitless	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}
5850	1.41		0.02822	19.68	1.29		0.02590	18.06	1.09				
5900		36.830				30.788				1.350	35.052	0.02700	18.83
5950	1.39		0.02772	19.33	1.27		0.02542	17.73	1.09				
6000		38.220				32.058				1.335	36.395	0.02670	18.62
6050	1.37		0.02733	19.06	1.25		0.02508	17.49	1.09				
6100		39.590				33.308				1.300	37.712	0.02600	18.13
6150	1.33		0.02666	18.59	1.22		0.02446	17.06	1.09				
6200		40.920				34.528				1.275	39.000	0.02550	17.78
6250	1.31		0.02613	18.22	1.20		0.02398	16.72	1.09				
6300		42.230				35.728				1.244	40.260	0.02489	17.36
6350	1.28		0.02558	17.84	1.17		0.02347	16.[illegible]	1.09				
6400		43.510				36.898				1.214	41.488	0.02429	16.94
6450	1.25		0.02504	17.46	1.15		0.02297	16.02	1.09				
6500		44.760				38.048				1.185	42.688	0.02370	16.53
6550	1.22		0.02441	17.02	1.12		0.02238	15.61	1.09				
6600		45.980				39.168				1.165	43.863	0.02330	16.25
6650	1.19		0.02388	16.65	1.10		0.02191	15.28	1.09				
6700		47.170				40.268				1.135	45.013	0.02270	15.83
6750	1.16		0.02325	16.21	1.07		0.02132	14.87	1.09				
6800		48.330				41.338				1.105	46.133	0.02210	15.41
6850	1.13		0.02257	15.74	1.01		0.02015	14.05	1.12				
6900		49.460			0.904	42.348	0.01807	12.60		1.085	47.228	0.02170	15.13
6950	1.09		0.02187	15.25	0.968		0.01936	13.50	1.13				
7000		50.550				43.316				1.049	48.295	0.02099	14.64
7050	1.06		0.02117	14.76	0.971		0.01942	13.54	1.09				

Table 2.1 Solar Radiation Distribution with Wavelergth based on a Solar Constant of 2.00 g cal cm^{-2} (1395 watt m^{-2}) (Cont'd)

WAVE LENGTH	EXTRATERRESTRIAL SOLAR RADIATION (I_E) NBS (Refs. 2.6 and 2.7)				SOLAR RADIATION FOR ONE (1.00) AIR MASS ($I_{1.00}$) NBS (Refs. 2.6 and 2.7)				ATMOSPHERIC TRANSMITTANCE	EXTRATERRESTRIAL SOLAR RADIATION MEAN OF JOHNSON (Ref. 2.3) and NICOLET (Ref. 2.4)			
λ	per 100 Angstroms				per 100 Angstroms				RATIO (M)	per 100 Angstroms			
	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		$I_E / I_{1.00}$	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY	
Angstroms (Å)	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	Unitless	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}
7100		51.610				44.287				1.029	49.334	0.02059	14.36
7150	1.02		0.02046	14.27	0.913		0.01827	12.74	1.12				
7200		52.630			0.826	45.200	0.01652	11.52		1.0[illegible]	[illegible].348	0.02000	13.95
7250	0.989		0.01979	13.80	0.875		0.01751	12.21	1.13				
7300		53.620				46.075				0.980	51.339	0.01960	13.67
7350	0.956		0.01912	13.33	0.877		0.01754	12.23	1.09				
7400		54.575				46.952				0.945	52.301	0.01890	13.18
7450	0.923		0.01847	12.88	0.810		0.01620	11.30	1.14				
7500		55.498				47.762				0.925	53.236	0.01850	12.90
7550	0.893		0.01787	12.46	0.703		0.01407	9.81	1.27				
7600		56.371			0.640	48.465	0.01279	8.92					
7650	0.868		0.01737	12.11	0.775		0.01550	10.81	1.12				
7700		57.259				49.240							
7750	0.848		0.01696	11.83			0.01556	10.85	1.09				
7800		58.107			0.778	50.018							
7850	0.830		0.01660	11.58	0.761		0.01523	10.62	1.09				
7900		58.937				50.779							
7950	0.814		0.01628	11.35	0.746		0.01493	10.41	1.09				
8000		59.751				51.525				0.819	57.596	0.01639	11.43
8050	0.796		0.01593	11.11	0.705		0.01410	9.83	1.13				
8100		60.547			0.668	52.230	0.01336	9.32					
8150	0.779		0.01559	10.87	0.690		0.01380	9.62	1.13				
8200		61.326				52.920							
8250	0.764		0.01529	10.66	0.701		0.01402	9.78	1.09				
8300		62.090				53.621							

Table 2.1 Solar Radiation Distribution with Wavelength based on a Solar Constant of 2.00 g cal cm^{-2} (1395 watt m^{-2})(Cont'd)

WAVE-LENGTH	EXTRATERRESTRIAL SOLAR RADIATION (I_E) NBS (Refs. 2.6 and 2.7)				SOLAR RADIATION FOR ONE (1.00) AIR MASS ($I_{1.00}$) NBS (Refs. 2.6 and 2.7)				ATMOSPHERIC TRANSMITTANCE	EXTRATERRESTRIAL SOLAR RADIATION MEAN OF JOHNSON (Ref. 2.3) and NICOLET (Ref. 2.4)			
	per 100 Angstroms				per 100 Angstroms				RATIO (M)	per 100 Angstroms			
λ	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		I_E / $I_{1.00}$	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY	
Angstroms (Å)	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	Unitless	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}
8350	0.748		0.01496	10.43	0.686		0.01372	9.57	1.09				
8400		62.838				54.307							
8450	0.732		0.01464	10.21	0.67[illegible]		0.01344	9.37	1.09				
8500		63.570				54.979				0.735	61.481	0.01470	10.25
8550	0.717		0.01434	10.00	0.657		0.01315	9.17	1.09				
8600		64.287				55.636							
8650	0.702		0.01405	9.80	0.644		0.01289	8.99	1.09				
8700		64.989				56.280							
8750	0.689		0.01378	9.61	0.604		0.01209	8.43	1.14				
8800		65.678				56.884							
8850	0.677		0.01354	9.44	0.533		0.01065	7.43	1.27				
8900		66.355				57.417							
8950	0.662		0.01325	9.24	0.505		0.01011	7.05	1.31				
9000		67.017				57.922				0.660	64.968	0.01321	9.21
9050	0.650		0.01301	9.07	0.475		0.00949	6.62	1.37				
9100		67.667				58.397							
9150	0.637		0.01273	8.88	0.424		0.00849	5.92	1.50				
9200		68.304				58.821							
9250	0.625		0.01250	8.72	0.378		0.00757	5.28	1.65				
9300		68.929				59.199							
9350	0.612		0.01225	8.54	0.358		0.00716	4.99	1.71				
9400		69.541				59.557							
9450	0.601		0.01202	8.38	0.426		0.00852	5.94	1.41				
9500		70.142				59.983				0.595	68.106	0.01190	8.30
9550	0.589		0.01177	8.21	0.487		0.00974	6.79	1.21				

Table 2.1 Solar Radiation Distribution with Wavelength based on a Solar Constant of 2.00 g cal cm^{-2} (1395 watt m^{-2})(Cont'd)

WAVE-LENGTH	EXTRATERRESTRIAL SOLAR RADIATION (I_E) NBS (Refs. 2.6 and 2.7)				SOLAR RADIATION FOR ONE (1.00) AIR MASS ($I_{1.00}$) NBS (Refs. 2.6 and 2.7)				ATMOSPHERIC TRANSMITTANCE	EXTRATERRESTRIAL SOLAR RADIATION MEAN OF JOHNSON (Ref. 2.3) and NICOLET (Ref. 2.4)			
λ	per 100 Angstroms				per 100 Angstroms				RATIO (M)	per 100 Angstroms			
	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		$I_E / I_{1.00}$	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY	
Angstroms (Å)	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	Unitless	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}
9600		70.731				60.470							
9650	0.577		0.01154	8.05	0.506		0.01012	7.06	1.14				
9700		71.308				60.376							
9750	0.566		0.01131	7.89	0.510		0.01020	7.11	1.11				
9800		71.874				61.486							
9850	0.554		0.01108	7.73	0.508		0.01017	7.09	1.09				
9900		72.428				61.994							
9950	0.544		0.01088	7.59	0.499		0.00998	6.96	1.09				
10000		72.972				62.493				0.535	70.931	0.01070	7.46
10050	0.533		0.01065	7.43	0.489		0.00978	6.82	1.09				
10100		73.505				62.982							
10150	0.521		0.01043	7.27	0.478		0.00956	6.67	1.09				
10200		74.026				63.460							
10250	0.512		0.01024	7.14	0.470		0.00939	6.55	1.09				
10300		74.538				63.930							
10350	0.502		0.01004	7.00	0.460		0.00921	6.42	1.09				
10400		75.040				64.390							
10450	0.491		0.00982	6.85	0.450		0.00901	6.28	1.09				
10500		75.531				64.84[illegible]							
10550	0.482		0.00963	6.72	0.442		0.00885	6.17	1.09				
10600		76.013				65.282							
10650	0.472		0.00943	6.58	0.433		0.00866	6.04	1.09				
10700		76.485				65.715							
10750	0.462		0.00923	6.44	0.424		0.00847	5.91	1.09				
10800		76.947				66.139							

Table 2.1 Solar Radiation Distribution with Wavelength based on a Solar Constant of 2.00 g cal cm^{-2} (1395 watt m^{-2})(Cont'd)

WAVE-LENGTH	EXTRATERRESTRIAL SOLAR RADIATION (I_E) NBS (Refs. 2.6 and 2.7)				SOLAR RADIATION FOR ONE (1.00) AIR MASS ($I_{1.00}$) NBS (Refs. 2.6 and 2.7)				ATMOSPHERIC TRANSMITTANCE	EXTRATERRESTRIAL SOLAR RADIATION MEAN OF JOHNSON (Ref. 2.3) and NICOLET (Ref. 2.4)			
	per 100 Angstroms				per 100 Angstroms				RATIO (M)	per 100 Angstroms			
λ	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		$I_E / I_{1.00}$	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY	
Angstroms (Å)	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	Unitless	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}
10850	0.452		0.00903	6.30	0.414		0.00829	5.78	1.09				
10900		77.399				66.553							
10950	0.441		0.00883	6.16	0.405		0.00810	5.65	1.09				
11000		77.840			0.330	66.958	0.00660	4.60		0.435	75.781	0.00870	6.07
11100					0.275		0.00551	3.84					
11200					0.242		0.00485	3.38					
11300					0.254		0.00508	3.54					
11400					0.269		0.00538	3.75					
11500	0.399		0.00798	5.57	0.285		0.00571	3.98	1.40				
11600					0.301		0.00602	4.20					
11700					0.313		0.00627	4.37					
11800					0.323		0.00645	4.50					
11900					0.328		0.00655	4.57					
12000		81.830			0.329	69.877	0.00658	4.59		0.360	79.756	0.00720	5.02
12100					0.327		0.00654	4.56					
12200					0.322		0.00644	4.49					
12300					0.313		0.00627	4.37					
12400					0.301		0.00602	4.20					
12500	0.330		0.00659	4.60	0.292		0.00584	4.07	1.13				
12600					0.279		0.00558	3.89					
12700					0.283		0.00566	3.95					
12800					0.280		0.00559	3.90					
12900					0.271		0.00542	3.78					
13000		85.130			0.247	72.832	0.00493	3.44		0.300	83.056	0.00599	4.18
13100					0.227		0.00455	3.17					

Table 2.1 Solar Radiation Distribution with Wavelength based on a Solar Constant of 2.00 g cal cm^{-2} (1395 watt m^{-2})(Cont'd)

WAVE-LENGTH	EXTRATERRESTRIAL SOLAR RADIATION (I_E) NBS (Refs. 2.6 and 2.7)				SOLAR RADIATION FOR ONE (1.00) AIR MASS ($I_{1.00}$) NBS (Refs. 2.6 and 2.7)				ATMOSPHERIC TRANSMITTANCE	EXTRATERRESTRIAL SOLAR RADIATION MEAN OF JOHNSON (Ref. 2.3) and NICOLET (Ref. 2.4)			
	per 100 Angstroms				per 100 Angstroms				RATIO(M)	per 100 Angstroms			
λ	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		$I_E / I_{1.00}$	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY	
Angstroms (Å)	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	Unitless	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}
13200					0.202		0.00404	2.82					
13300					0.189		0.00377	2.63					
13400					0.172		0.00344	2.40					
13500	0.274		0.00548	3.82	0.153		0.00305	2.13	1.79				
13600					0.136		0.00272	1.90					
13700					0.004		0.00007	0.05					
13800					0.007		0.00014	0.10					
13900					0.007		0.00014	0.10					
14000		87.870			0.072	74.088	0.00143	1.00		0.250	85.806	0.00500	3.49
14100					0.120		0.00239	1.67					
14200					0.128		0.00257	1.79					
14300					0.129		0.00258	1.80					
14400					0.129		0.00258	1.80					
14500	0.223		0.00447	3.12	0.129		0.00258	1.80	1.73				
14600					0.129		0.00258	1.80					
14700					0.130		0.00261	1.82					
14800					0.137		0.00274	1.91					
14900					0.146		0.00291	2.0[illegible]					
15000		90.100			0.153	75.378	0.00307	2.14		0.205	88.081	0.00410	2.86
15100					0.163		0.00326	2.27					
15200					0.168		0.00337	2.35					
15300					0.171		0.00343	2.39					
15400					0.166		0.00333	2.32					
15500	0.178		0.00355	2.48	0.163		0.00327	2.28	1.09				
15600					0.158		0.00317	2.21					

Table 2.1 Solar Radiation Distribution with Wavelength based on a Solar Constant of 2.00 g cal cm^{-2} (1395 watt m^{-2})(Cont'd)

WAVE-LENGTH	EXTRATERRESTRIAL SOLAR RADIATION (I_E) NBS (Refs. 2.6 and 2.7)				SOLAR RADIATION FOR ONE (1.00) AIR MASS ($I_{1.00}$) NBS (Refs. 2.6 and 2.7)				ATMOSPHERIC TRANSMITTANCE	EXTRATERRESTRIAL SOLAR RADIATION MEAN OF JOHNSON (Ref. 2.3) and NICOLET (Ref. 2.4)			
	per 100 Angstroms				per 100 Angstroms				RATIO (M)	per 100 Angstroms			
λ	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		$I_E / I_{1.00}$	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY	
Angstroms (Å)	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	Unitless	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}
15700					0.156		0.00311	2.17					
15800					0.151		0.00303	2.11					
15900					0.148		0.00295	2.06					
16000		91.880			0.144	76.970	0.00288	2.01		0.175	89.981	0.00350	2.44
16100					0.140		0.00280	1.95					
16200					0.138		0.00275	1.92					
16300					0.132		0.00264	1.84					
16400					0.129		0.00258	1.80					
16500	0.136		0.00273	1.90	0.125		0.00250	1.74	1.09				
16600					0.122		0.00244	1.70					
16700					0.118		0.00237	1.65					
16800					0.115		0.00231	1.61					
16900					0.112		0.00224	1.56					
17000		93.240			0.108	78.227	0.00217	1.51		0.140	91.556	0.00280	1.95
17100					0.105		0.00211	1.47					
17200					0.102		0.00204	1.42					
17300					0.099		0.00198	1.38					
17400					0.096		0.00192	1.34					
17500	0.101		0.00202	1.41	0.091		0.00182	1.27	1.11				
17600					0.082		0.00163	1.14					
17700					0.075		0.00151	1.05					
17800					0.070		0.00139	0.970					
17900					0.062		0.00125	0.870					
18000		94.250			0.056	79.091	0.00112	0.780		0.115	92.831	0.00229	1.60
18100					0.014		0.00029	0.200					

Table 2.1 Solar Radiation Distribution with Wavelength based on a Solar Constant of 2.00 g cal cm^{-2} (1395 watt m^{-2}) (Cont'd)

WAVE-LENGTH	EXTRATERRESTRIAL SOLAR RADIATION (I_E) NBS (Refs. 2.6 and 2.7)				SOLAR RADIATION FOR ONE (1.00) AIR MASS ($I_{1.00}$) NBS (Refs. 2.6 and 2.7)				ATMOSPHERIC TRANSMITTANCE	EXTRATERRESTRIAL SOLAR RADIATION MEAN OF JOHNSON (Ref. 2.3) and NICOLET (Ref. 2.4)			
	per 100 Angstroms				per 100 Angstroms				RATIO (M)	per 100 Angstroms			
λ	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		$I_E / I_{1.00}$	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY	
Angstroms (Å)	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	Unitless	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}
18200					0.004		0.00007	0.050					
18300					0.004		0.00007	0.050					
18400					0.004		0.00007	0.050					
18500	0.0771		0.00154	1.07	0.004		0.00007	0.050	21.0				
18600					0		0	0					
18700					0.004		0.00007	0.050					
18800					0.007		0.00014	0.100					
18900					0		0	0					
19000		95.021			0.014	79.167	0.00029	0.200		0.095	93.881	0.00189	1.3[illegible]
19100					0.048		0.00096	0.670					
19200					0.067		0.00133	0.930					
19300					0.066		0.00132	0.920					
19400					0.065		0.00129	0.900					
19500	0.0662		0.00132	0.923	0.062		0.00125	0.870	1.09				
19600					0.062		0.00125	0.870					
19700					0.062		0.00123	0.860					
19800					0.057		0.00113	0.790					
19900					0.046		0.00092	0.640					
20000		95.693			0.045	79.725	0.00090	0.630		0.080	94.756	0.00161	1.12
20100					0.050		0.00100	0.700					
20200					0.057		0.00113	0.790					
20300					0.054		0.00109	0.760					
20400					0.054		0.00108	0.750					
20500	0.0580		0.00116	0.809	0.053		0.00106	0.740	1.09				
20600					0.052		0.00105	0.730					

Table 2.1 Solar Radiation Distribution with Wavelength based on a Solar Constant of 2.00 g cal cm^{-2} (1395 watt m^{-2}) (Cont'd)

WAVE-LENGTH	EXTRATERRESTRIAL SOLAR RADIATION (I_E) NBS (Refs. 2.6 and 2.7)				SOLAR RADIATION FOR ONE (1.00) AIR MASS ($I_{1.00}$) NBS (Refs. 2.6 and 2.7)				ATMOSPHERIC TRANSMITTANCE	EXTRATERRESTRIAL SOLAR RADIATION MEAN OF JOHNSON (Ref. 2.3) and NICOLET (Ref. 2.4)			
λ	per 100 Angstroms				per 100 Angstroms				RATIO (M)	per 100 Angstroms			
	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY		$I_E / I_{1.00}$	PERCENT OF EXTRA-TERRESTRIAL TOTAL		INTENSITY	
Angstroms (Å)	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}	Unitless	%	Accumulative %	g-cal cm^{-2}	watt m^{-2}
20700					0.052		0.00103	0.720					
20800					0.052		0.00103	0.720					
20900					0.050		0.00100	0.700					
21000		96.263			0.049	80.246	0.00099	0.690		0.070	95.506	0.00140	0.977
21500	0.0497		0.00099	0.693	0.046		0.00091	0.636	1.09				
22000		96.760				80.706				0.060	96.156	0.00120	0.837
22500	0.0457		0.00091	0.637	0.042		0.00083	0.580	1.09				
23000		97.217				81.126				0.050	96.706	0.00100	0.697
23500	0.0414		0.00083	0.578	0.038		0.00076	0.530	1.09				
24000		97.631				81.506				0.040	97.156	0.00080	0.558
24500	0.0390		0.00078	0.544	0.036		0.00072	0.500	1.09				
25000		98.021				81.866				0.035	97.531	0.00070	0.488
27500	0.0178		0.00032	0.223	0.004		0.00009	0.060	37.0				
30000		98.911				81.886				0.022	98.64[illegible]	0.00044	0.310
32500	0.0099		0.00018	0.124	0		0	0	∞	0.012		0.00025	0.173
35000		99.406									99.261		
37500	0.0059		0.00011	0.075	0		0	0	∞	0.007		0.00015	0.103
40000		99.702									99.631		
42500	0.0036		0.00006	0.045	0		0	0	∞	0.004		0.00009	0.063
45000		99.862									99.856		
47500	0.0024		0.00002	0.017	0		0	0	∞	0.003		0.00006	0.040
50000	0	100.002	0	0	0	81.886	0	0	—	0	100.001	0	0
TOTAL AREA UNDER CURVE			2.00	1395			1.64	1142				2.00	1395

where

I_N = Intensity of solar radiation for "N" air mass thickness (Table 2.1)

I_o = Extra-terrestrial solar radiation (Table 2.1)

M = Atmospheric transmittance

N = Number of air masses.

Equation (2.4) can also be used to obtain intensities versus wavelengths for other total normal incident intensities (area under curve) by computation of new values of atmospheric transmittance as follows:

$$M_N = M \frac{I_{TN}}{1.64} \qquad \text{Eq. (2.5)}$$

where

I_{TN} = New value of total normal incident intensity

M = Value for atmospheric transmittance given in Table 2.1

M_N = New value of atmospheric transmittance.

Equations (2.4) and (2.5) are valid only for locations near the earth's surface (below 5 km altitude). For higher altitudes, corrections would be needed for the change of the amount of ozone and water vapor in the atmosphere. Also Equation (2.5) should be used only for values of I_{TN} greater than 1.10 g-cal cm^{-2} min^{-1} since values lower than this would indicate a considerably higher ratio of water vapor to ozone in the atmosphere and require that the curve be adjusted to give more absorption in the infrared water vapor bands without as large an increase in the ozone absorption.

Also included in Table 2.1 is the extraterrestrial solar radiation (solar radiation outside the atmosphere). There are two sets of data, both obtained by extrapolating from measured values through one or more air masses of atmosphere. The data from the National Bureau of Standards give the intensity for a high resolution (g-cal cm^{-2} 100 $Å^{-1}$) as obtained from the data presented in Table 2.1 for one air mass. To provide extraterrestrial solar radiation data below 2995 Å, values are given to less resolution (g-cal cm^{-2} 10000 $Å^{-1}$) based on mean values of Johnson (Ref. 2.3) and Nicolet (Ref. 2.4), with data for the

entire spectrum for comparison purposes. The data were converted to g-cal cm^{-2} 100 $\mathring{A}^{-1}$ to make the values agree with the NBS data. It is the belief of the author that the error in using the mean value of Johnson and Nicolet is less than the actual error of the figures presented.

2.3 Total Solar Radiation.

2.3.1 Introduction.

The standard solar radiation sensors measure the intensity of direct solar radiation from the sun falling on a horizontal surface plus the diffuse (sky) radiation from the total sky hemisphere. Diffuse radiation is lowest with dry clear air; it increases with increasing dust and moisture in the air; with extremely dense clouds or fog, the measured horizontal solar radiation will be nearly all diffuse radiation. The higher values of measured horizontal solar radiation (extremes, 95 percentile) will occur during clear skies. When solar radiation data are used in design studies, the direct solar radiation should be applied from one direction as parallel rays and at the same time the diffuse radiation should be applied as rays from all directions of a hemisphere to the object as shown in Figure 2.1.

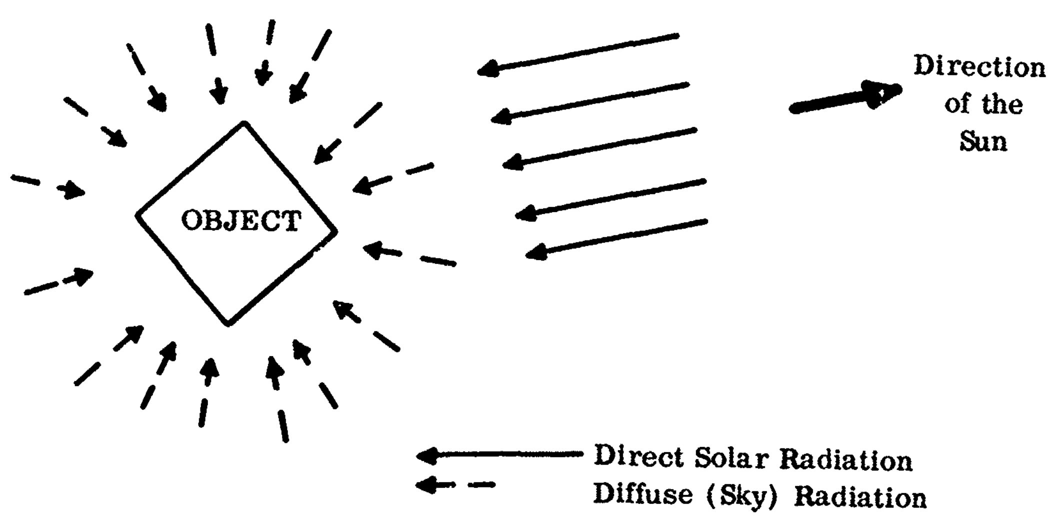

Figure 2.1 METHOD OF APPLYING DIFFUSE RADIATION FOR DESIGN

In this document all solar radiation values given are intensities. Solar radiation intensities are measured in gram calories per square centimeter (same as langleys per square centimeter) at U. S. Weather Bureau stations. Intensities of solar radiation are numerically equal to solar insolation per minute; i.e., gram calories per square centimeter per minute.

2.3.2 Basic Data Computation.

The solar radiation data given in the tables in this section were obtained from a study made by the National Weather Records Center of the Weather Bureau under contract to the NASA-Marshall Space Flight Center.

The basic data used were total horizontal solar and sky radiation (I_{TH}) for each hour of the day for ten year periods at two stations - Apalachicola, Florida and Santa Maria, California. Intensities were computed by dividing each hourly value by 60. The diffuse sky radiation intensities (I_{dH}) were empirically estimated for each value, based on amount of total horizontal solar and sky radiation and solar altitude similar to the method used in Reference 2.11. After subtracting the diffuse sky radiation from the total horizontal solar and sky radiation, the resultant horizontal solar radiation (I) can be used to compute the direct normal incident solar radiation (I_{DN}) using the following equation (Refs. 2.12 and 2.13):

$$I_{DN} = \frac{I}{\sin b} \qquad \text{Eq. (2.6)}$$

where

I_{DN} = Direct Normal Incident Solar Radiation

I = Horizontal Solar Radiation = $I_{TH} - I_{dH}$

b = Sun's Altitude (Ref. 2.14).

The total normal incident solar radiation (I_{TN}) values were found by adding the direct normal incident solar radiation (I_{DN}) and the diffuse sky radiation (I_{dH}) previously estimated. This method of finding the total normal incident solar radiation may result in a slight overestimation of the value for low solar altitudes because the sky hemisphere is intercepted by the ground

surface, but this error will be small enough to be ignored when working with extreme values, or any values on the high end of the frequency distribution (i.e., mean plus one sigma or greater).

Total solar radiation intensities on a south-facing surface, with the normal to the surface at 45 degrees to the horizontal, were found as follows:

$$I_{D45} = I(\sin 45° + \cot b \cos a \cos 45°) \qquad \text{Eq. (2.7)}$$

where

I_{D45} = Intensity of direct solar radiation on a south-facing surface, with normal 45 degrees to the horizontal.

I = Horizontal Solar Radiation = $I_{TH} - I_{dH}$

a = Sun's azimuth measured from south direction

b = Sun's altitude.

The values of Total Intensity on a south-facing surface, with normal 45 degrees to the horizontal were found by adding the direct solar radiation on the south facing surface, with normal 45 degrees to horizontal (I_D 45°) and the diffuse sky radiation (I_{DF}) previously estimated.

2.3.3 Solar Radiation Extremes.

To present the solar radiation data, the month of June was selected to represent the extremes during summer and the longest days and December, to represent the extremes during winter and the shortest days. The June extreme normal incident solar radiation data for Santa Maria, California, were increased for the period from 1100 to 1900 hours to reflect the higher values which occur early in July (first week) during the afternoon. Tables 2.2 and 2.3 give the solar radiation extreme data for time of day. The values given for diffuse radiation are the highest values associated with the other extremes of solar radiation given and not the extremes of diffuse radiation that occurred during the period of record. Since the diffuse radiation is low with high values of total measured solar radiation, the values given are considerably lower than the highest values of diffuse radiation which occurred during the period, and the values for association with the extremes are less than those for the 95 percentile. Figure 2.2 shows the June total horizontal and total normal incident data in graphical form for the Eastern Test Range, New Orleans, Gulf Transportation, and Huntsville.

TABLE 2.2 EXTREME VALUES OF SOLAR RADIATION FOR THE WESTERN TEST RANGE, WEST COAST TRANSPORTATION, SACRAMENTO, AND WHITE SANDS MISSILE RANGE

TIME OF DAY (Local Standard Time)	Total Horizontal Solar Radiation g-cal cm^{-2}		Diffuse Radiation Associated with Total Horizontal Solar Radiation Extremes g-cal cm^{-2}		Total Normal Incident Solar Radiation g-cal cm^{-2}		Total 45° Surface Solar Radiation g-cal cm^{-2}	
JUNE								
	EXTREME	95 Percentile	EXTREME	95 Percentile	EXTREME	95 Percentile	EXTREME	95 Percentile
0500	0	0	0	0	0	0	0	0
0600	0.16	0.11	.02	.04	1.14	0.78	0.04	0
0700	0.46	0.40	.05	.08	1.34	1.08	0.19	0.16
0800	0.82	0.76	.06	.09	1.54	1.38	0.34	0.31
0900	1.16	1.11	.04	.08	1.74	1.62	0.84	0.77
1000	1.45	1.42	0	.03	1.79	1.71	1.19	1.12
1100	1.64	1.56	0	.10	1.79	1.69	1.39	1.31
1200	1.69	1.63	0	.08	1.74	1.68	1.49	1.38
1300	1.69	1.64	0	.07	1.74	1.68	1.49	1.70
1400	1.59	1.54	.06	.12	1.74	1.68	1.34	1.29
1500	1.45	1.39	0	.06	1.79	1.70	1.14	1.09
1600	1.21	1.19	0	.02	1.79	1.71	0.89	0.78
1700	0.87	0.83	.03	.05	1.69	1.60	0.34	0.18
1800	0.46	0.42	.05	.08	1.39	1.23	0.19	0.13
1900	0.14	0.12	.02	.04	1.19	0.93	0.04	0
2000	0	0	0	0	0	0	0	0
DECEMBER								
	EXTREME	95 Percentile	EXTREME	95 Percentile	EXTREME	95 Percentile	EXTREME	95 Percentile
0800	0	0	0	0	0	0	0	0
0900	0.35	0.32	0.04	0.05	1.59	1.39	0.99	0.85
1000	0.65	0.60	0.03	0.05	1.64	1.53	1.29	1.21
1100	0.86	0.80	[illegible]	0.04	1.84	1.64	1.64	1.49
1200	0.96	0.89	0.02	0.06	1.79	1.69	1.74	1.63
1300	0.99	0.89	0	0.06	1.84	1.70	1.79	1.64
1400	0.85	0.80	0.01	0.04	1.79	1.64	1.59	1.49
1500	0.66	0.60	0.02	.05	1.69	1.54	1.34	1.21
1600	0.38	0.31	0.02	0.05	1.64	1.38	1.04	0.87
1700	0	0	0	0	0	0	0	0

TABLE 2.3 EXTREME VALUES OF SOLAR RADIATION FOR EASTERN TEST RANGE, NEW ORLEANS, GULF TRANSPORTATION, HUNTSVILLE

TIME OF DAY (Local Standard Time)	Total Horizontal Solar Radiation g-cal cm^{-2}		Diffuse Radiation Associated with Total Horizontal Solar Radiation Extremes g-cal cm^{-2}		Total Normal Incident Solar Radiation g-cal cm^{-2}		Total 45° Surface Solar Radiation g-cal cm^{-2}	
JUNE								
	EXTREME	95 Percentile	EXTREME	95 Percentile	EXTREME	95 Percentile	EXTREME	95 Percentile
0500	0	0	0	0	0	0	0	0
0600	0.12	0.07	0	0	1.09	1.00	0	0
0700	0.42	0.36	0.05	0.07	1.29	1.04	0.19	0.16
0800	0.82	0.71	0.04	0.10	1.59	1.30	0.34	0.27
0900	1.23	1.02	0	0.10	1.59	1.48	0.49	0.41
1000	1.35	1.30	0.02	0.06	1.59	1.54	0.99	0.95
1100	1.52	1.45	0.03	0.09	1.59	1.54	1.19	1.14
1200	1.58	1.53	0.10	0.16	1.64	1.55	1.29	1.24
1300	1.58	1.50	0.10	0.20	1.64	1.53	1.29	1.24
1400	1.50	1.44	0.05	0.12	1.59	1.52	1.19	1.09
1500	1.35	1.30	0.02	0.06	1.59	1.52	1.04	0.95
1600	1.10	1.01	0.05	0.12	1.54	1.44	0.54	0.44
1700	0.77	0.72	0.05	0.09	1.49	1.33	0.34	0.30
1800	0.48	0.40	0.03	0.06	1.44	1.14	0.19	0.18
1900	0.11	0.08	0	0	1.14	1.00	0.14	0.03
2000	0	0	0	0	0	0	0	0
DECEMBER								
	EXTREME	95 Percentile	EXTREME	95 Percentile	EXTREME	95 Percentile	EXTREME	95 Percentile
0700	0	0	0	0	0	0	0	0
0800	0.16	0.10	0	0	1.34	1.12	0.64	0.50
0900	0.46	0.42	0.04	0.06	1.44	1.36	0.94	0.89
1000	0.79	0.71	0.01	0.07	1.69	1.60	1.39	1.29
1100	0.95	0.92	0.02	0.04	1.79	1.68	1.64	1.56
1200	1.09	1.02	0	0.03	1.79	1.70	1.74	1.66
1300	1.05	1.02	0	0.03	1.79	1.78	1.74	1.6[illegible]
1400	0.94	0.89	0.02	0.05	1.74	1.67	1.59	1.63
1500	0.79	0.70	0	0.03	1.74	1.57	1.39	1.27
1600	0.46	0.41	0.04	0.06	1.54	1.40	0.99	0.91
1700	0.16	0.10	0	0	1.34	1.12	0.64	0.50
1800	0	0	0	0	0	0	0	0

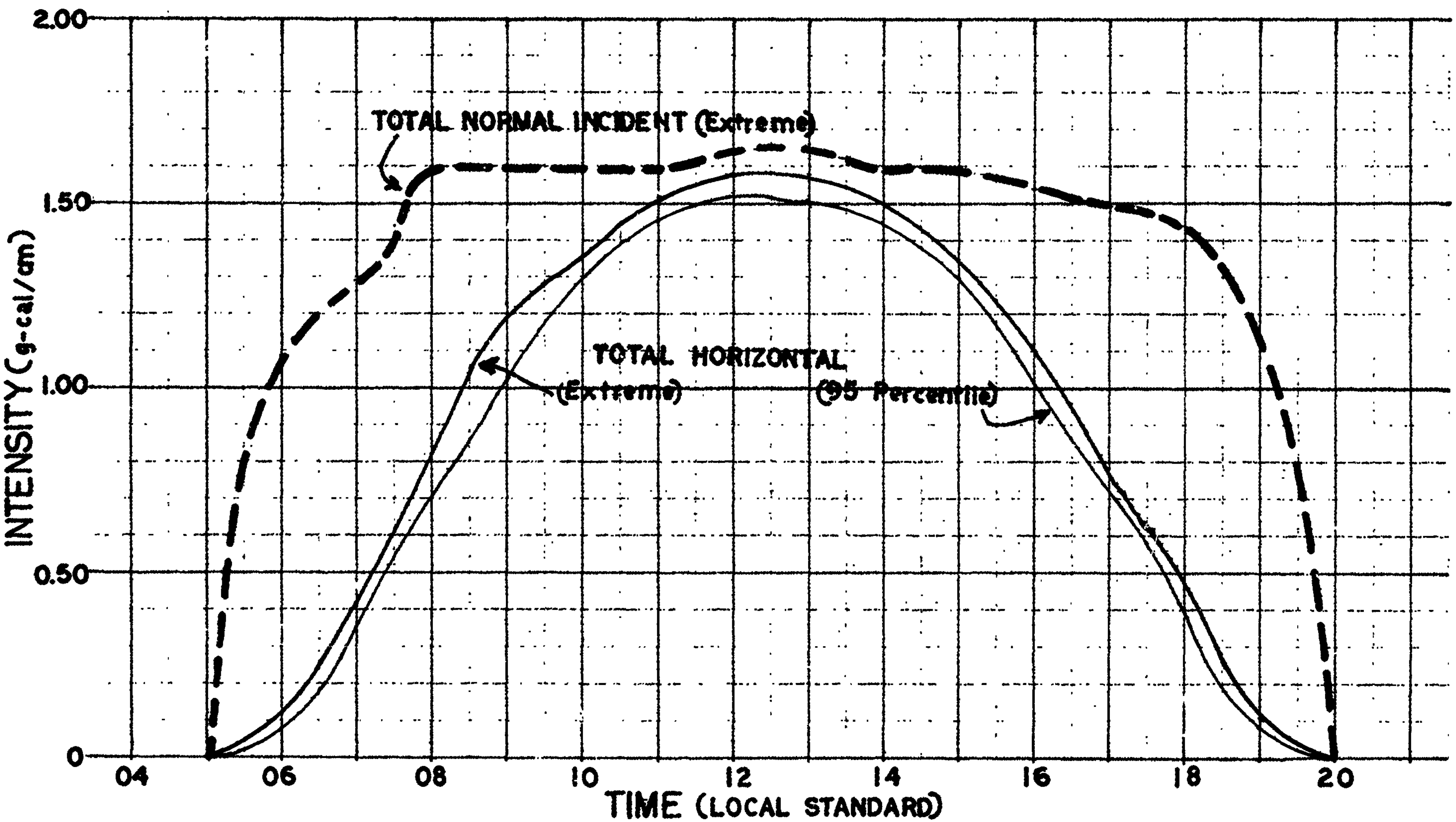

FIGURE 2.2 JUNE EXTREME VALUES OF SOLAR RADIATION FOR EASTERN TEST RANGE, NEW ORLEANS, GULF TRANSPORTATION, AND HUNTSVILLE.

2.3.4 Variation with Altitude.

Solar radiation intensity on a surface will increase with altitude above the earth's surface, with clear skies, in accordance with the following equation:

$$I_H = I_{DN} + (2.00 - I_{DN})\left(1 - \frac{\rho_H}{\rho_S}\right) \qquad \text{Eq. (2.8)}$$

where

I_H = Intensity of solar radiation normal to surface at required height,

I_{DN} = Intensity of solar radiation normal to surface at the earth's surface, assuming clear skies ($I_{DN} = I_{TN} - I_{dH}$)

ρ_H = Atmospheric density at required height (from U. S. Standard Atmosphere Data or this document) (kg m^{-3})

ρ_S = Atmospheric density at sea level (1.2250 kg m^{-3} from U. S. Standard Atmosphere Ref. 1.15)

2.00 = Solar constant (g-cal cm^{-2}).

The diffuse radiation (I_{dH}) decreases with altitude above the earth's surface, with clear skies. A good estimate of the value can be obtained from the following equation:

$$I_{dH} = 0.7500 - 0.4076\, I_H \qquad \text{Eq. (2.9)*}$$

Equation (2.9) is valid for values of I_H from Equation (2.8) up to 1.84 g-cal cm^{-2}. For values of I_H greater than 1.84 g-cal cm^{-2}, $I_{dH} = 0$,

---

* Equation (2.9) is based on a cloudless and dust free atmosphere.

where

I_{dH} = Intensity of diffuse radiation

I_H = Intensity of solar radiation normal to surface.

2.3.5 Solar Radiation during Extreme Conditions.

When ground winds occur which exceed the 95, 99, or 99.9 percentile steady-state winds given in this document in Section V, the associated weather normally is such that clouds, rain, or dust are generally present; therefore, the intensity of the incoming solar radiation would be less than the maximum values given in Tables 2.2 and 2.3. Maximum values of solar radiation intensity to use with corresponding wind speeds are given in Table 2.4.

2.3.6 Solar Radiation in Space.

The assumption in equation (2.8) is that the distance from the sun is one astronomical unit. When this distance differs from one astronomical unit, adjustment can be made using the following equation:

$$I_{ND} = \frac{2.00}{D^2} \qquad \text{Eq. (2.10)}$$

where

I_{ND} = Intensity of solar radiation normal to the surface at required distance (D) from the sun

D = Distance from the sun in astronomical units.

Solar radiation may be reflected or re-radiated by the Earth or other solar bodies. The nature of the reflected radiation or re-radiation is extremely complex because of the constant changing relative positions of the Earth, Sun, and other bodies. The reflected radiation and re-radiation could reach a maximum value of about 3.00 g-cal cm^{-2} in addition to the direct solar radiation, but normally the Earth contributed radiation is about 1.00 g-cal cm^{-2} or less. Further information on computation of these values can be obtained from references 2.16, 2.17, 2.18, and 2.19.

TABLE 2.4 SOLAR RADIATION MAXIMUM VALUES ASSOCIATED WITH EXTREME WIND VALUES

	Maximum Solar Radiation					
Steady-State Ground Wind Speed at 18 m Height	Huntsville, New Orleans River Transportation, Gulf Transportation, Eastern Test Range, Western Test Range, Sacramento, West Coast Transportation and Wallops Test Range			White Sands Missile Range		
($m\ sec^{-1}$)	($kJm^{-2}\ sec^{-1}$)	(g-$cal\ cm^{-2}\ min^{-1}$)	($BTU\ ft^{-2}\ hr^{-1}$)	($kJm^{-2}\ sec^{-1}$)	(g-$cal\ cm^{-2}\ min^{-1}$)	($BTU\ ft^{-2}\ hr^{-1}$)
10	0.84	1.20	265	1.05	1.50	332
15	0.56	0.80	177	0.70	1.00	221
≥20	0.35	0.50	111	0.56	0.80	177

2.4 Air Temperature Near the Surface.

Surface air temperatures are presented in Table 2.5 for various geographic areas. The maximum extremes and minimum extremes and the 95 percentile values for each extreme are given for the worst month based on 50 years of record. Values for extreme minimum sky radiation (equal to outgoing radiation) are also given in Table 2.5. The surface air temperature extreme values presented in Table 2.5 will be expected for only a few hours during a day. Generally, the extreme maximum temperature is reached after 12 noon and before 5 p.m., while the minimum temperature is reached just before sunrise. Table 2.6 shows the maximum and minimum air temperatures which have occurred on each hour at the Eastern Test Range (Cape Kennedy), but not necessarily on the same day.

2.5 Extreme Air Temperature Change.

Design values of extreme air temperature changes (thermal shock).

a. For all areas these values are:

(1) An increase of air temperature of 10°C (18°F) with a simultaneous increase of solar radiation (measured on a normal surface) from 0.50 g-cal cm^{-2} min^{-1} (110 BTU ft^{-2} hr^{-1}) to 1.85 g-cal cm^{-2} min^{-1} (410 BTU ft^{-2} hr^{-1}) may occur in a one-hour period. Likewise, the reverse change of the same magnitude may occur for decreasing air temperature and solar radiation.

(2) A 24-hour change may occur with an increase of 27.7° (50°F) in air temperature in a 5-hour period, followed by four hours of constant air temperature, then a decrease of 27.7°C (50°F) in a five-hour period, followed by ten hours of constant air temperature.

b. For Eastern Test Range (Cape Kennedy, Florida), the 99.9 percentile air temperature changes are as follows (Ref. 2.20):

(1) An increase of air temperature of 5.6°C (11°F) with a simultaneous increase of solar radiation (measured on a normal surface) from 0.50 g cal cm^{-2} min^{-1} (110 BTU ft^{-2} hr^{-1}) to 1.60 g cal cm^{-2} min^{-1} (354 BTU ft^{-2} hr^{-1}), or a decrease of air temperature of 9.4°C (17°F) with a simultaneous decrease of solar radiation from 1.60 g cal cm^{-2} min^{-1} (354 BTU ft^{-2} hr^{-1}) to 0.50 g cal cm^{-2} min^{-1} (110 BTU ft^{-2} hr^{-1}) may occur in a one-hour period.

TABLE 2.5 SURFACE AIR AND SKY RADIATION TEMPERATURE EXTREMES

Area		Surface Air Temperature Extremes**				Sky Radiation	
		Maximum		Minimum		Equivalent Temperature Minimum Extreme	Equivalent Radiation g-cal cm^{-2} min^{-1}
		Extreme	95%	Extreme	95%		
Huntsville	°C	43.9	41.7	-23.3	-21.7	-30.0	0.28
	°F	111	107 #	-10	-7#	-22	
River Transportation	°C	43.9	-	-30.6	-	-37.2	0.25
	°F	111	-	-23	-	-35	
New Orleans	°C	37.8	31.7	-12.8	7.8	-17.8	0.35
	°F	100	89 ⌿	9	46 ⌿	0	
Gulf Transportation	°C	40.6	-	-12.8	-	-17.8	0.35
	°F	105	-	9	-	0	
Eastern Test Range	°C	37.2	30.0	- 2.2	12.2	-15.0	0.36
	°F	99	86 ⌿	28	54 ⌿	5	
Panama Canal Transportation	°C	41.7	-	-12.8	-	-15.0	0.36
	°F	107	-	9	-	5	
Western Test Range	°C	41.7	31.1	- 2.2	3.9	-15.0	0.36
	°F	107	88 ⌿	28	39 ⌿	5	
West Coast Transportation	°C	46.1	-	- 6.1	-	-17.8	0.35
	°F	115	-	21	-	0	
Sacramento	°C	46.1	*	- 6.1	*	-17.8	0.35
	°F	115	*	21	*	0	
White Sands Missile Range	°C	41.1	*	-21.1	*	-30.0	0.28
	°F	106	*	- 6	*	-22	
Wallops Test Range	°C	39.4	*	-11.7	*	-17.8	0.35
	°F	103	*	11	*	0	

⌿ Based on hourly data

Based on Worst Month extremes

- Not applicable

* To be determined.

** The extreme maximum and minimum temperatures will be encountered during periods of wind speeds less than about one meter per second.

TABLE 2.6 MAXIMUM AND MINIMUM SURFACE AIR TEMPERATURES AT EACH HOUR FOR EASTERN TEST RANGE*

Time	Annual Maximum		Annual Minimum	
	°C	°F	°C	°F
1 a.m.	28.9	84	1.1	34
2	28.9	84	0.6	33
3	29.4	85	-1.1	30
4	28.3	83	-0.6	31
5	28.3	83	-1.1	30
6	29.4	85	-1.1	30
7	30.6	87	-1.7	29
8	30.6	87	-2.2	28
9	31.7	89	-0.6	31
10	33.9	93	1.1	34
11	35.0	95	2.2	36
12 noon	35.6	96	5.0	41
1 p.m.	37.2	99	5.6	42
2	35.6	97	5.0	41
3	35.6	97	5.6	42
4	35.6	97	5.6	42
5	35.6	97	5.6	42
6	35.0	95	3.9	39
7	33.3	92	2.2	36
8	31.7	89	2.2	36
9	30.0	86	1.7	35
10	30.0	86	1.7	35
11	30.0	86	1.1	34
12 mid	30.0	86	1.1	34

* Based on 10 years of record for Patrick AFB and Cape Kennedy.

(2) A 24-hour temperature change may occur as follows. An increase of 16.1°C (29°F) in air temperature (wind speed under 5 m/sec) in an eight-hour period, followed by two hours of constant air temperature (wind speed under 5 m/sec), then a decrease of 21.7°C (39°F) in air temperature (wind speed between 7 and 10 m/sec) in a 14-hour period.

2.6 Surface (Skin) Temperature.

The temperature of the surface of an object exposed to solar, day sky or night sky radiation is usually different than the air temperature (Refs. 2.21 and 2.22). The amount of the extreme difference in temperature between the object and the surrounding air temperature is given in Table 2.7 and Figure 2.3, Part A, for exposure to a clear night (or day)* sky or to the sun on a clear day. Since the flow of air across an object changes the balance between the heat transfers from radiation and convection-conduction between the air and the object, the difference in the temperature between the air and the object will decrease with increasing wind speed (Ref. 2.21). Part B of Figure 2.3 provides information for making the correction for wind speed. Values are tabulated in Table 2.7 for various wind speeds.

2.7 Compartment Temperature.

2.7.1 Introduction.

A thin material enclosing an air space will conduct the heat of the material to the air next to the cover when heated by solar radiation (or cooled by the night sky). This results in the compartment air space being frequently considerably hotter or cooler than the surrounding air (See 2.6 above). The temperature reached in a compartment is dependent on the location of the air space with respect to the heated surface, the type and thickness of the surface material, the type of construction, and the insulation; i.e., an addition of a layer of insulation on the inside of the surface will greatly reduce the heating or cooling of the air in the compartment space from radiation (Refs. 2.23 and 2.24).

2.7.2 Compartment Extreme High Temperature.

A compartment probable extreme high temperature of 87.8°C (190°F) for a period of one hour and 65.6°C (150°F) for a period of six hours must be considered at all geographic locations while aircraft or other transportation equipment are stationary on the ground without air conditioning in the compartment. These extremes will be found at the top and center of the compartment.

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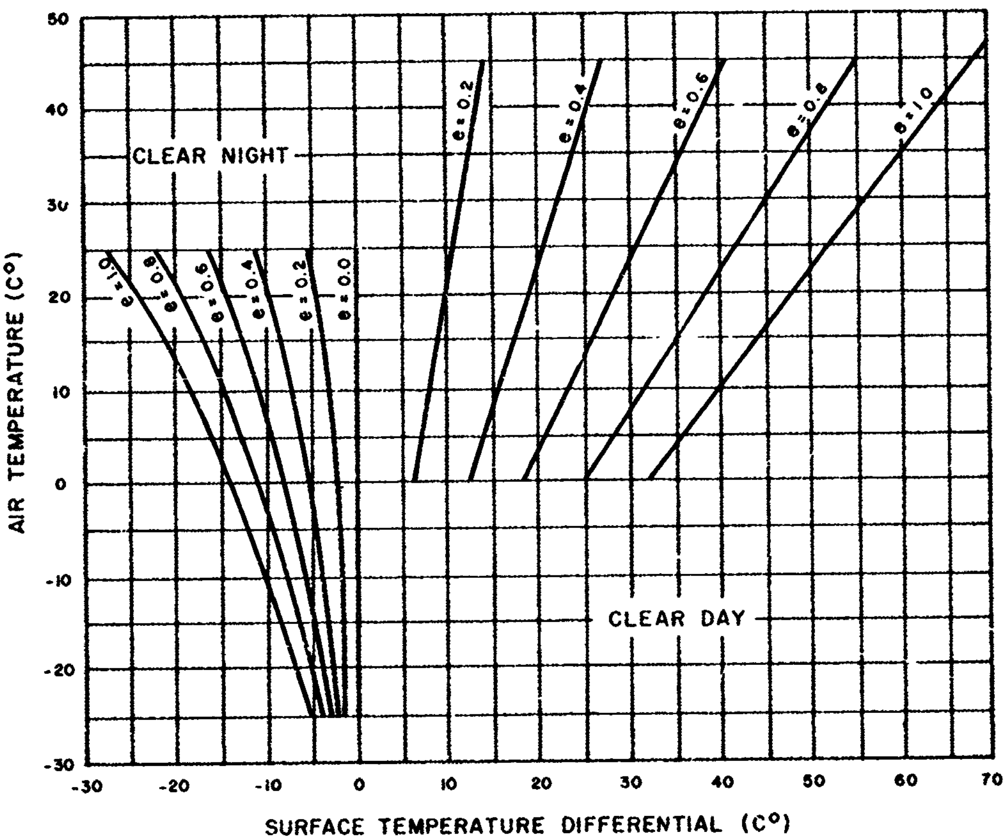
* Without sun's rays striking.



A. SURFACE TEMPERATURE DIFFERENTIALS WITH RESPECT TO AIR TEMPERATURE FOR SURFACE OF EMITTANCE FROM 0.0 TO 1.0 FOR CALM WIND CONDITIONS. TEMPERATURE DIFFERENCE AFTER CORRECTION FOR WIND IS TO BE ADDED OR SUBTRACTED TO THE AIR TEMPERATURE TO GIVE SURFACE (SKIN) TEMPERATURE

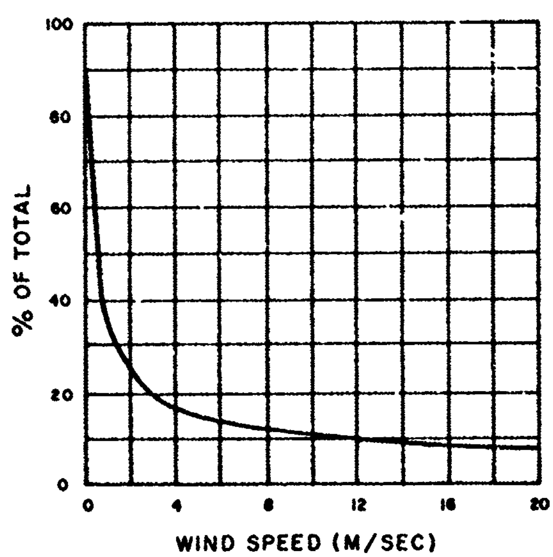


FIGURE 2.3 EXTREME SURFACE (SKIN) TEMPERATURE OF AN OBJECT NEAR THE EARTH'S SURFACE (0 TO 300 m) FOR CLEAR SKY

B. CORRECTION FOR WIND SPEED OBTAINED FROM GRAPH A. VALID ONLY FOR A PRESSURE OF ONE ATMOSPHERE.

TABLE 2.7 EXTREME SURFACE (SKIN) TEMPERATURE ABOVE OR BELOW AIR TEMPERATURE OF AN OBJECT NEAR THE EARTH'S SURFACE

Air Temperature	Clear Night					Clear Day				
	Wind Speed ($m\ sec^{-1}$)					Wind Speed ($m\ sec^{-1}$)				
	0	2	4	10	20	0	2	4	10	20
(°C)	Surface Temperatures (°C)					Surface Temperatures (°C)				
-25	- 5.0	-1.1	-0.8	-0.2	-0.15					
-20	- 6.5	-1.5	-1.0	-0.3	-0.2					
-15	- 8.0	-1.8	-1.3	-0.4	-0.2					
-10	-10.0	-2.3	-1.6	-0.4	-0.3					
- 5	-12.0	-2.7	-1.9	-0.5	-0.4					
0	-14.2	-3.2	-2.3	-0.6	-0.4	32.0	7.3	5.1	1.4	1.0
5	-16.6	-3.8	-2.7	-0.7	-0.5	36.0	8.2	5.8	1.6	1.1
10	-19.2	-4.4	[illegible]	-0.9	-0.6	40.0	9.1	6.4	1.8	1.2
15	-22.0	-5.0	[illegible]	-1.0	-0.7	44.0	10.0	7.0	2.0	1.3
20	-25.0	-5.7	[illegible]	-1.1	-0.8	48.0	10.9	7.7	2.2	1.4
25	-28.0	-6.4	-4.5	-1.3	-0.8	52.0	11.8	8.3	2.3	1.6
30						56.0	12.7	9.0	2.5	1.7
35						60.0	13.6	9.6	2.7	1.8
40						64.0	14.5	10.2	2.9	1.9
45						68.0	15.4	10.9	3.1	2.0

Note: Values are given for an emittance value of 1.0. Temperature differences for other emittance can be determined by multiplying tabular value by the appropriate emittance.

2.7.3 Compartment Extreme Cold Temperatures during aircraft flight, when compartments not heated, are given in Table 2.8.

TABLE 2.8 COMPARTMENT DESIGN COLD TEMPERATURE EXTREMES FOR ALL LOCATIONS

Maximum Flight Altitude (Geometric) Of Aircraft Used For Transport		Compartment Cold Temperature Extreme	
(m)	(ft)	(°C)	(°F)
4,550	15,000	-35.0	-31
6,100	20,000	-45.0	-49
7,600	25,000	-53.3	-64
9,150	30,000	-65.0	-85
15,200	50,000	-86.1	-123

2.8 Data on temperature distribution with altitude are given in Section XIV.

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SECTION III. HUMIDITY

By

Glenn E. Daniels

3.1 Definitions. (Ref. 3.1)

Dew point is the temperature to which a given parcel of air must be cooled at constant pressure and constant water vapor content in order for saturation to occur. Further cooling below the dew point normally produces condensation either in liquid or solid form.

Relative humidity is the ratio of the actual amount of water vapor in a given volume of air to the amount of water vapor that the same volume of air at the same temperature would hold if saturated. Values given are in percent.

Vapor concentration (previously called absolute humidity (Ref. 3.2)) is the ratio of the mass of water vapor present to the volume occupied by the mixture, i.e., the density of the water vapor content. This is expressed in grams of water vapor per cubic meter of air.

Water vapor is water in gaseous state.

3.2 Vapor Concentration.

Water in vapor form in the atmosphere is invisible; however, the amount of liquid water available from a volume of warm air near saturation is considerable and must be considered in design of space vehicles because:

a. Small solid particles (dust) which settle on surfaces cause condensation (frequently when the atmosphere is not at the saturation level) and will dissolve. The resultant solution may be corrosive. Galvanic corrosion resulting from contact of dissimilar metals also takes place at a rapid rate in the presence of moisture. The rate of corrosion of the surface increases with higher humidity (Ref. 3.3). (See Section X of this document for further details.)

b. Humidity conditions can impair the performance of electrical equipment. This may be by an alteration of the electrical constants of tuned circuits, deterioration of parts (resistors, capacitors, etc.), electrical breakdown of air gaps in high-voltage areas, or shorting of sections by conductive solutions formed from solid particles dissolving in the liquid formed.

c. Bacteria and fungi usually require high humidities associated with high temperatures to grow well.

d. A decrease in the temperature of the air to the dew point will result in condensation of water from the atmosphere in liquid or frozen form. Considerable difficulty may result from ice forming on space vehicles when moist air is cooled by the low temperature of the fuel used, especially if pieces of this ice should drop into equipment areas of the vehicle or supporting ground equipment before or during takeoff. Optical surfaces (such as lenses of television cameras) may become coated with water droplets or ice crystals which prevent their use.

Tests are specified for environmental testing (humidity) for aeronautical equipment in MIL-E-5272C (ASG) 13 April 1959 (Ref. 3.4) and are included in MIL-STD-810 (USAF) (Ref. 3.5). These tests specify temperatures of 71.1°C (160°F) at a relative humidity of 95 percent ± 5 percent for 10 cycles of 6 hours each over a total period of 240 hours. This represents dew points of 68.9°C (156°F), values far higher than any natural extreme. Dew points much above 32.2°C (90°F) are extremely unlikely in nature (Ref. 3.6), since the dew point is limited by the source of the moisture, that is the surface temperature of the water body from which the water evaporates (see Ref. 3.7, maps following page 235 for average ocean temperatures). The tests proposed can be used advantageously only as aggravated tests where high temperatures are not significant in the test after correlation of deterioration with that encountered in natural extremes. Therefore, the referenced Military Specifications should be used as guidelines in conjunction with this document.

3.2.1 High Vapor Concentration at Surface.

a. Huntsville, River Transportation, New Orleans, Gulf Transportation, Eastern Test Range, and Wallops Test Range:

(1) The following extreme humidity cycle of 24 hours with a steady-state wind of less than 5 m sec^{-1} (9.7 knots) should be considered in design: Six hours of 37.2°C (99°F) air temperature at 50 percent relative humidity and a vapor concentration of 26.9 g m^{-3} (11.7 gr ft^{-3}); six hours of decreasing air temperature to 24.4°C (76°F) with relative humidity increasing to 100 percent (saturation); eight hours of decreasing air temperature to 21.1°C (70°F), with a release of 3.9 grams of water as liquid per cubic meter of air (1.7 gr ft^{-3}), humidity remaining at 100 percent; and four hours of increasing air temperature to 37.2°C (99°F) and a decrease to 41 percent relative humidity.

(2) An extreme relative humidity between 75 and 100 percent and air temperature between 22.8 C (73° F) and 27.8 C (82° F), which would result in corrosion and bacterial and fungal growths, can be expected for a period of 15 days. A humidity of 100 percent occurs one-fourth of the time at the lower temperature in cycles not exceeding 24 hours. Any loss of water vapor from the air by condensation is replaced from outside sources so that 75 percent relative humidity is maintained at the higher temperature.

b. Panama Canal Transportation:

(1) The following extreme humidity cycle of 24 hours with a steady-state wind of less than 5 m sec^{-1} (9.7 knots) should be considered in design: Six hours of 32.2 C (90° F) air temperature at 75 percent relative humidity, and a vapor concentration of 25.4 g m^{-3} (11.1 gr ft^{-3}); six hours of decreasing air temperature to 26.7° C (80° F) with relative humidity increasing to 100 percent; eight hours of decreasing air temperature to 21.7° C (71° F) with a release of 6.3 grams of water as liquid per cubic meter of air (2.8 gr of water per cubic foot of air), humidity remaining at 100 percent; two hours of increasing air temperature to 26.7° C (80° F) and a decrease to 75 percent relative humidity; and two hours of increasing air temperature to 32.2° C (90° F) with the relative humidity remaining at 75 percent (moisture added to air by evaporation, mixing, or replacement with air of higher vapor concentration).

(2) An extreme relative humidity between 85 and 100 percent and air temperature between 23.9° C (75° F) and 26.1° C (79° F), which would result in corrosion and bacterial and fungal growth, can be expected for a period of 30 days. The humidity should be 100 percent during one-fourth of the time at the lower temperature in cycles not exceeding 24 hours. Any loss of water vapor from the air by condensation is replaced from outside sources so that at least 85 percent relative humidity is maintained at the higher temperature.

(3) Equipment shipped from the West Coast, through the Panama Canal transported by ship may accumulate moisture (condensation) while in the ship's hold because of the increasing moisture content of the air while traveling south to the Panama Canal, and the slower increase of temperature of the equipment being transported. This condensation may result in corrosion, rusting, or other deterioration of the equipment (Ref. 3.8). Extreme values of condensation are:

(a) Maximum condensation conditions occur during the period between December and March, but condensation conditions may occur during all months.

(b) The maximum dew point expected is 30.0°C (86°F), with dew points over 21.1°C (70°F) for ship travel of 6 days prior to arrival at the Panama Canal from the west coast, and for the remainder of the trip to Cape Kennedy.

c. Western Test Range, West Coast Transportation, and Sacramento:

(1) The following extreme humidity cycle of 24 hours with a steady-state wind of less than 5 m sec^{-1} (9.7 knots) should be considered in design: Six hours of 23.9°C (75°F) air temperature at 75 percent relative humidity and a vapor concentration of 16.2 g m^{-3} (7.9 gr ft^{-3}); six hours of decreasing air temperature to 18.9°C (66°F) with relative humidity increasing to 100 percent; eight hours of decreasing air temperature to 12.8°C (55°F) with a release of 5.0 grams of water as liquid per cubic meter of air (2.2 gr of water per ft^3 of air), humidity at 100 percent; and four hours of increasing air temperature to 23.9°C (75°F) and the relative humidity decreasing to 52 percent.

(2) Bacterial and fungal growth should present no problem because of the lower temperatures in this area. For corrosion, an extreme humidity of between 75 and 100 percent relative humidity and air temperature between 18.3°C (65°F) and 23.3°C (74°F) can be expected for a period of 15 days. The humidity should be 100 percent during one-fourth of the time at the lower temperature in cycles not exceeding 24 hours. Any loss of water vapor from the air by condensation should be replaced from outside sources to maintain at least 75 percent relative humidity at the higher temperature.

d. White Sands Missile Range: At this location, a high-vapor concentration need not be considered.

3.2.2 Low Vapor Concentration at Surface.

3.2.2.1 Introduction. Low water-vapor concentration can occur when the air temperatures are very low or at high temperature when the air is very dry. In both cases, the dew points are very low. However, in the case of low dew points and high temperatures, the relative humidity is low. When any storage area or compartment of a vehicle is heated to temperatures well above the ambient air temperature (such as the high temperatures of the storage area in an aircraft standing on the ground in the sun), the relative humidity will be even lower than the relative humidity of the ambient air. These two types of low water-vapor concentrations have entirely different environment effects. In the case of low air temperatures, ice or condensation may form on equipment while in the high temperature--low humidity condition; organic materials may dry and split or

otherwise deteriorate. When a storage area (or aircraft) is considerably warmer than the ambient air (even when the air is cold), the drying increases even more. Low relative humidities may also result in another problem - that of static electricity. Charges on equipment could ignite fuel or result in shocks to personnel when discharged. Because of this, two types of low water-vapor concentrations (dry extremes) are given for the surface.

3.2.2.2 Surface Extremes of Low Vapor Concentration.

a. Huntsville, River Transportation, Wallops Test Range, and White Sands Missile Range:

(1) A vapor concentration of 2.1 g m^{-3} (0.9 gr ft^{-3}), with an air temperature of -11.7° C (+11° F) and a relative humidity between 98 and 100 percent for a duration of 24 hours, must be considered.

(2) A vapor concentration of 4.5 g m^{-3} (2.0 gr ft^{-3}), corresponding to a dew point of -1.1° C (30° F) at an air temperature of 28.9° C (84° F) and a relative humidity of 15 percent occurring for 6 hours each 24 hours, and a maximum relative humidity of 34 percent at an air temperature of 15.6° C (60° F) for the remaining 18 hours of each 24 hours for a 10-day period, must be considered.

b. New Orleans, Gulf Transportation, Panama Canal Transportation, and Eastern Test Range:

(1) A vapor concentration of 4.2 g m^{-3} (1.8 gr ft^{-3}), with an air temperature of -2.2° C (28° F) and a relative humidity of 98 to 100 percent for a duration of 24 hours, must be considered.

(2) A vapor concentration of 5.6 g m^{-3} (2.4 gr ft^{-3}), corresponding to a dew point of 2.2° C (36° F) at an air temperature of 22.2° C (72° F) and a relative humidity of 29 percent occurring for 8 hours, and a maximum relative humidity of 42 percent at an air temperature of 15.6° C (60° F) for the remaining 16 hours of each 24 hours for 10 days, must be considered.

c. Eastern Test Range:

(1) A vapor concentration of 4.2 g m^{-3} (1.8 gr ft^{-3}), with an air temperature of -2.2° C (28° F) and a relative humidity of 98 to 100 percent for a duration of 24 hours, must be considered.

(2) A vapor concentration of 4.8 g m^{-3} (2.1 gr ft^{-3}), corresponding to a dew point of 0.0°C (32°F) at an air temperature of 37.8°C (100°F) and a relative humidity of 11 percent occurring for 4 hours each 24 hours, and a maximum relative humidity of 26 percent at an air temperature of 21.1°C (70°F) for the remaining 20 hours of each 24 hours for 10 days, must be considered.

d. West Coast Transportation and Sacramento:

(1) A vapor concentration of 3.1 g m^{-3} (1.4 gr ft^{-3}), with an air temperature of -6.1°C (21°F) and a relative humidity of 98 to 100 percent for a duration of 24 hours, must be considered.

(2) A vapor concentration of 10.1 g m^{-3} (4.4 gr ft^{-3}), corresponding to a dew point of 11.1°C (52°F) at an air temperature of 37.8°C (100°F) and a relative humidity of 22 percent occurring for 4 hours each 24 hours, and a maximum relative humidity of 55 percent at an air temperature of 21.1°C (70°F)

3.2.3 Compartment Vapor Concentration at Surface.

A low water-vapor concentration extreme of 10.1 g m^{-3} (4.4 gr ft^{-3}), corresponding to a dew point of 11.1°C (52°F) at a temperature of 87.8°C (190°F) and a relative humidity of two percent occurring for one hour, a linear change over a four-hour period to an air temperature of 37.8°C (100°F) and a relative humidity of 22 percent occurring for 15 hours, then a linear change over a four-hour period to the initial conditions, must be considered at all locations.

3.3 Vapor Concentration at Altitude.

In general, the vapor concentration decreases with altitude in the troposphere. This is because the decrease of temperature with altitude means a decrease in the maximum vapor concentration (Saturated vapor pressure decreases with decreasing temperature).

3.3.1 High Vapor Concentration at Altitude.

The following tables present the relationship between maximum vapor concentration and the associated temperature normally expected as a function of altitude.

a. Maximum Vapor Concentrations for Eastern Test Range, Table 3.1.

b. Maximum Vapor Concentrations for Wallops Test Range, Table 3.2.

c. Maximum vapor concentrations for White Sands Missile Range, Table 3.3.

TABLE 3.1. MAXIMUM VAPOR CONCENTRATION FOR EASTERN TEST RANGE

Geometric Altitude	Vapor Concentration			Temperature Associated with Maximum Vapor Concentration	
(km)	(ft)	(g m^{-3})	(gr ft^{-3})	(°C)	(°F)
SRF (0.005 MSL)	(16)	27.0	11.8	30.5	87
1	3,300	1[illegible].0	8.3	24.5	76
2	6,600	13.3	5.8	18.0	64
3	9,800	9.3	4.1	12.0	54
4	13,100	6.3	2.8	5.5	42
5	16,400	4.5	2.0	-0.5	31
6	19,700	2.9	1.3	-6.8	20
7	23,000	2.0	0.9	-13.0	9
8	26,200	1.2	0.5	-20.0	-4
9	29,500	0.6	0.3	-27.0	-17
10	32,800	0.3	0.1	-34.5	-30
10 to 20	32,800 to 65,600	0.3	0.1	-34.5	-30

TABLE 3.2. MAXIMUM VAPOR CONCENTRATION FOR WALLOPS TEST RANGE

Geometric Altitude	Vapor Concentration			Temperature Associated with Maximum Vapor Concentration	
(km)	(ft)	(g m^{-3})	(gr ft^{-3})	(°C)	(°F)
SRF (0.002 MSL)	(8)	22.5	9.8	27.5	81
1	3,300	20.0	8.7	26.1	79
2	6,600	13.9	6.1	17.2	63
3	9,800	10.3	4.5	12.8	55
4	13,100	7.4	3.2	7.8	46
5	16,400	6.0	2.6	2.8	37
6	19,700	3.9	1.7	-1.1	30
7	23,000	2.6	1.1	-5.0	23
8	26,200	1.7	0.7	-11.1	12
9	29,500	0.9	0.4	-17.8	0
10	32,800	0.4	0.2	-27.8	-18
10 to 20	32,800 to 65,600	0.4	0.2	-27.8	-18

TABLE 3.3. MAXIMUM VAPOR CONCENTRATION FOR WHITE SANDS MISSILE RANGE

Geometric Altitude		Vapor Concentration		Temperature Associated with Maximum Vapor Concentration	
(km)	(ft)	(g m^{-3})	(gr ft^{-3})	(° C)	(° F)
SRF (1.2 MSL)	(3, 989)	16.0	7.0	21.5	70
2	6, 600	13.2	5.8	18.9	66
3	9, 800	9.0	3.9	12.8	55
4	13, 100	6.8	3.0	7.8	46
5	16, 400	4.9	2.1	2.2	36
6	19, 700	3.4	1.5	-2.2	28
7	23, 000	2.2	1.0	-10.0	14
8	26, 200	1.3	0.6	-16.1	3
9	29, 500	0.6	0.3	-22.8	-9
10	32, 800	0.2	0.1	-30.0	-22
10 to 20	32, 800 to 65, 600	0.2	0.1	-30.0	-22

3.3.2 Low Vapor Concentration at Altitude

The values presented as low extreme vapor concentrations in the following tables are based on data measured by standard radiosondes GMD/1A.

a. Minimum Vapor Concentrations for Eastern Test Range, Table 3.4.

b. Minimum Vapor Concentrations for Wallops Test Range, Table 3.5.

c. Minimum Vapor Concentrations for White Sands Missile Range, Table 3.6.

TABLE 3.4. MINIMUM VAPOR CONCENTRATIONS FOR EASTERN TEST RANGE

Geometric Altitude		Vapor Concentration		Temperature Associated with Minimum Vapor Concentration	
(km)	(ft)	(g m^{-3})	(gr ft^{-3})	(°C)	(°F)
SRF (0.005 MSL)	(16)	4.0	1.7	29	84.2
1	3, 300	0.5	0.2	6	42.8
2	6, 600	0.2	0.1	0	32.0
3	9, 800	0.1	0.04	-6	21.2
4	13, 100	<0.1	<0.04	-11	12.2

TABLE 3.5. MINIMUM VAPOR CONCENTRATION FOR WALLOPS TEST RANGE

Geometric Altitude		Vapor Concentration		Temperature Associated with Minimum Vapor Concentration	
(km)	(ft)	(g m^{-3})	(gr ft^{-3})	(°C)	(°F)
SRF (0.002 MSL)	(8)	0.5	0.2	-4	24.8
1	3,300	0.3	0.1	-11	12.2
2	6,600	0.2	0.1	-17	1.4
3	9,800	0.2	0.1	-23	-9.4
4	13,100	0.2	0.1	-31	-23.8
5	16,400	0.1	0.04	-39	-38.2
to	to				
10	32,800	0.1	0.04	-39	-38.2

TABLE 3.6. MINIMUM VAPOR CONCENTRATION FOR WHITE SANDS MISSILE RANGE

Geometric Altitude		Vapor Concentration		Temperature Associated with Minimum Vapor Concentration	
(km)	(ft)	(g m^{-3})	(gr ft^{-3})	(°C)	(°F)
SRF (1.2 MSL)	(3,989)	1.2	0.5	-1	30.2
2	6,600	0.9	0.4	-5	23.0
3	9,800	0.6	0.3	-12	10.4
4	13,100	0.4	0.2	-20	-4.0
5	16,400	0.2	0.1	-26	-4.8
6	19,700	0.1	0.04	-32	-25.6
7	23,000	0.1	0.04	-34	-29.2
8	26,200	0.1	0.04	-38	-36.4
9	29,500	0.1	0.04	-39	-38.2
10	32,800	0.1	0.04	-39	-38.2

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SECTION IV. PRECIPITATION

By

Glenn E. Daniels

4.1 Definitions. (Ref. 4.1)

Precipitation is defined as all forms of hydrometeors, whether liquid or solid, which are free in the atmosphere and which may or may not reach the ground. Accumulation is reported in inches of depth for liquid and ice, or in inches of depth of water equivalent, of frozen water particles.

Snow is defined as all forms of frozen precipitation except large hail; it includes snow pellets, snow grains, ice crystals, ice pellets, and small hail.

Hail is precipitation in the form of balls or irregular lumps of ice, and always is produced by convective clouds. Through established convention, the diameter of hail must be 5 mm or more, and the specific gravity between 0.60 and 0.92.

Ice pellets are precipitation in the form of transparent, more or less globular, hard grains of ice under 5 mm in diameter, that rebound when striking hard surfaces.

Small hail is precipitation in the form of semitransparent, round or conical grains of frozen water under 5 mm in diameter. Each grain consists of a nucleus of soft hail (ball of snow) surrounded by a very thin ice layer. They are not crisp and do not usually rebound when striking a hard surface.

Precipitable water is the total atmospheric water vapor contained in a vertical column of unit cross-sectional area extending between any two specified levels. It is usually given as inches of water (if vapor were completely condensed).

4.2 Rain.

Although most long-duration rainfall world records (monthly or yearly) have been for regions far removed from the areas of interest for large space vehicle launch and test operations, the world maximum amount of short-duration rainfall has occurred or can occur in the thunderstorms or tropical storms within the United States, in the Gulf of Mexico, or in Canal Zone areas. A study

of the rate of rainfall, compared with duration, shows that the average rate (per hour) decreases as the duration increases. Equipment must withstand both prolonged soaking rain and brief downpours. The following precipitation values at an air temperature between 21.1°C (70°F) (night) and 32.2°C (90°F) (day) are adequate for most design problems, although considerably less than world record extremes.

4.2.1 Rainfall at Surface.

a. Extreme Amounts. The design rainfall for the areas of interest are as follows:

(1) Huntsville, Eastern Test Range, Western Test Range, Sacramento, West Coast Transportation, River Transportation, White Sands Missile Range, and Wallops Test Range, rainfall information is given in Table 4.1.

(2) Gulf Transportation, Panama Canal Transportation, and New Orleans rainfall information is given in Table 4.2.

TABLE 4.1 DESIGN RAINFALL RATES FOR HUNTSVILLE, EASTERN TEST RANGE, WESTERN TEST RANGE, SACRAMENTO, WEST COAST TRANSPORTATION, RIVER TRANSPORTATION, WALLOPS TEST RANGE, AND WHITE SANDS MISSILE RANGE

Time Period	1 min	1 hour	24 hours
Total Amount (mm)	7.6	64	305
(in.)	0.3	2.5	12
Rate (mm/hr)	456	64	13
(in./hr)	18.0	2.5	0.5
Average Drop Diameter (mm)	3.8	2.6	2.0
Average Rate of Fall (m/sec)	8.5	7.3	6.4
Peak Wind Speed (m/sec)	30	20	20
Average Wind Speed (m/sec)	17	6	4.5

TABLE 4.2 DESIGN RAINFALL RATES FOR GULF TRANSPORTATION, PANAMA CANAL, AND NEW ORLEANS

Time Period	1 min	1 hour	24 hours
Total Amount (mm)	12.7	102	508
(in.)	0.5	4	20
Rate (mm/hr)	762	102	21
(in./hr)	30.0	4.0	0.8
Average Drop Diameter (mm)	4.1	2.9	1.8
Average Rate of Fall (m/sec)	8.8	7.6	6.1
Peak Wind Speed (m/sec)	30	20	20
Average Wind Speed (m/sec)	17	6	4.5

b. Frequency of Nonoccurrence. The probability of nonoccurrence of precipitation exceeding a certain amount on any one day was determined by a study of six years of data at Cape Kennedy, Florida. This information is given in Table 4.3.

4.2.2 Rainfall at Altitude.

Rainfall rates normally decrease with altitude when rain is striking the ground. The rainfall rates at various altitudes in percent of the surface rates are given in Table 4.4 for all areas (Ref. 4.2).

The precipitation above the ground is generally colder than at the ground and frequently occurs as supercooled drops which can cause icing on any object moving through the drops. Such icing can be expected to occur when the air temperature is less than 2.2°C (36°F). For the geographic areas considered in this report, these conditions usually occur between 3 and 10 km altitude.

TABLE 4.3 PROBABILITY THAT PRECIPITATION WILL NOT EXCEED A SPECIFIC AMOUNT IN ANY ONE DAY, EASTERN TEST RANGE

AMOUNT (Inches)	MONTH					
	JAN %	FEB %	MAR %	APR %	MAY %	JUNE %
0.00	79.0	75.7	68.8	75.6	76.3	59.4
0.05	86.6	82.8	73.7	85.5	84.4	68.9
0.20	90.3	86.4	80.1	90.0	91.4	74.4
0.50	93.0	89.3	87.1	95.0	95.7	86.1
1.00	96.2	96.4	95.7	97.8	99.5	96.1
2.00	98.9	100.0*	98.9	100.0*	100.0*	98.9
5.00	100.0*	100.0*	99.5	100.0*	100.0*	100.0*

AMOUNT (Inches)	MONTH					
	JULY %	AUG %	SEPT %	OCT %	NOV %	DEC %
0.00	61.8	59.1	52.8	65.6	75.0	75.8
0.05	69.4	66.1	63.3	73.1	81.7	86.6
0.20	79.6	74.7	73.3	82.3	89.4	92.5
0.50	87.1	83.9	83.9	90.3	92.8	95.7
1.00	94.1	92.5	93.9	96.8	96.7	98.4
2.00	97.3	98.4	97.8	100.0*	100.0*	100.0*
5.00	100.0*	100.0*	100.0*	100.0*	100.0*	100.0*

*Although the data indicate no chance of exceeding certain amounts of precipitation during most of the months, it should be realized that the length of data studied is not long and that there is always a chance of any meteorological extreme of record being exceeded.

TABLE 4.4 DISTRIBUTION OF RAINFALL RATES WITH HEIGHT FOR ALL LOCATIONS

Height (Geometric) Above Surface (km)	Percent of Surface Rate
SRF	100
1	90
2	75
3	57
4	34
5	15
6	7
7	2
8	1
9	0.1
10 and over	< 0.1

4.3 Snow.

The accumulation of snow on a surface produces stress. For a flat horizontal surface, the stress is proportional to the weight of the snow directly above the surface. For long narrow objects, such as pipes or wires lying horizontally above a flat surface (which can accumulate the snow), the stress can be figured as approximately equal to the weight of the wedge of snow with the sharp edge along the object and extending above the object in both directions at about 45 degrees to the vertical. (In such cases, the snow load would be computed for the depth of snow above the edge of the object and not the total snow depth on the ground.) The weight of new fallen snow varies between 0.5 kg m^{-2} per cm of depth (0.26 lb ft^{-2} $in.^{-1}$) and 2.0 kg m^{-2} per cm of depth (1.04 lb ft^{-2} $in.^{-1}$), depending on the weather situation at the time of snowfall. When the amount is sufficient to be important in load design, the weight is near 1.0 kg m^{-2} cm^{-1} (0.52 lb ft^{-2} $in.^{-1}$). Snow on the ground becomes more dense and the depth decreases with time.

4.3.1 Snow Loads at Surface.

Maximum snow loads for the following areas are:

a. Huntsville, Wallops Test Range, and River Transportation areas. For horizontal surfaces a snow load of 25 kg m^{-2} (5.1 lb ft^{-2}) per 24-hour period (equivalent to a 10-inch snowfall) to a maximum of 50 kg m^{-2} (10.2 lb ft^{-2}) in a 72-hour period, provided none of the snow is removed from the surface during the period, should be considered for design purposes.

b. New Orleans, West Coast Transportation, White Sands Missile Range, and Sacramento areas. For horizontal surfaces, a maximum snow load of 10 kg m^{-2} (2.0 lb ft^{-2}) per one 24-hour period, should be considered for design purposes.

4.3.2 Snow Particle Size.

Snow particles may penetrate openings (often openings of minute size) in equipment and cause malfunction of mechanical or electrical components, either before or after melting. Particle size, associated wind speed, and air temperature to be considered are as follows:

a. Huntsville, Wallops Test Range, and River Transportation areas. Snow particles 0.1 mm (0.0039 in.) to 5 mm (0.20 in.) diameter; wind speed 10 m sec^{-1} (19 knots); air temperature -17.8°C (0°F).

b. New Orleans, West Coast Transportation, White Sands Missile Range, and Sacramento areas. Snow particles 0.5 mm (0.020 in.) to 5 mm (0.20 in.) diameter; wind speed 10 m sec^{-1} (19 knots); air temperature -5.0°C (23°F).

4.4 Hail.

Hail is one of the most destructive weather forces in nature, being equalled only by hurricanes and tornadoes. Hail normally forms in extremely well-developed thunderstorms during warm weather and rarely occurs in winter months or when the air temperature is below 0°C (32°F). Although the average diameter of hailstones is 8 mm (0.31 in.) (Ref. 4.3), hailstones larger than 12.7 mm (0.5 in.) in diameter frequently fall, while stones 50 mm (2.0 in.) in diameter can be expected annually somewhere in the United States. The largest measured hailstone in the United States was 137 mm (5.4 in.) in diameter and had a weight of 0.68 kg (1.5 lb) (Refs. 4.4, 4.5 and 4.6). Three environmental effects on equipment must be considered; they are as follows:

The accumulation of hail, as with snow, stresses the object by its weight. Although hail has a higher density than snow, 2.4 kg m^{-2} cm^{-1} (1.25 lb ft^{-2} $in.^{-1}$), the extreme load from hail will not exceed the extreme snow load at any area of interest; therefore, the snow load design will adequately cover any hail loads expected.

Large hailstones, because of weight and velocity of fall, are responsible for structural damage to property (Ref. 4.7). The actual designation of locations where hailstones, with specific sizes of hail, will fall is not possible. However, the following information can be used as a guide for design and scheduling (these values are most applicable to the design of ground support equipment and protective covering for the space vehicles during the transporting of vehicles between Huntsville and New Orleans). Hail as an abrasive is discussed in Section VI.

4.4.1 Hail at Surface.

a. Huntsville, River Transportation, Gulf Transportation, New Orleans, Wallops Test Range, and White Sands Missile Range.

(1) A maximum hailstone size of 50 mm (2 in.) in diameter with an occurrence probability of one time in 15 years.

(2) Damaging hailstorms occur most frequently between 3 p.m. and 9 p.m. during May through September. April is the month of highest frequency-of-occurrence of hailstorms for Huntsville, River Transportation, and Gulf Transportation. March is the month of highest frequency-of-occurrence of hailstorms for White Sands Missile Range, and May is the month of highest frequency-of-occurrence of hailstorms for Wallops Test Range.

(3) The period of large hail (over 25 mm in diameter) will not be expected to last more than 15 minutes and should have a maximum total accumulation of 50 mm (2 in.) for depth of hailstones on horizontal surfaces.

(4) Velocity of fall equals 30.5 m sec^{-1} (100 ft sec^{-1}) for each stone.

(5) Wind speed equals 10 m sec^{-1} (33 ft sec^{-1}).

(6) Density of hailstones equals 0.80 g cm^{-3} (50 lb ft^{-3}).

b. Eastern Test Range.

(1) A maximum hailstone size of 25.4 mm (1 in.) in diameter with an occurrence probability of one time in 30 years.

(2) Damaging hailstones occur most frequently between 3 p.m. and 9 p.m. during April through June. May is the month of highest frequency-of-occurrence for hailstorms.

(3) The period of large hail will not be expected to last more than 15 minutes and should have a maximum total accumulation of 12.5 mm (0.5 in.) for depth of hailstones on horizontal surfaces.

(4) Velocity of fall equals 20 m sec^{-1} (66 ft sec^{-1}) for each stone.

(5) Wind speed equals 10 m sec^{-1} (33 ft sec^{-1}).

(6) Density of hailstones equals 0.80 g cm^{-3} (50 lb ft^{-3}).

4.4.2 Distribution of Hail with Altitude.

Although it is not the current practice to design space vehicles for flight in thunderstorms, data on distribution with altitude are presented as an item of importance. The probability of hail increases with altitude from the surface to 5 km and then decreases rapidly with increasing height. Data on Florida thunderstorms, giving the number of times hail was encountered at various altitudes during aircraft flights (Ref. 4.8), are given in Table 4.5 for areas specified in paragraph 4.4.1.

TABLE 4.5 DISTRIBUTION OF HAIL WITH HEIGHT FOR ALL LOCATIONS (Ref. 4.8)

Height (Geometric) Above Surface (km)	Occurrence of Hail (percent of flights through thunderstorms)
2	0
3	3.5
5	10
6	4
8	3

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SECTION V. WIND

By

James R. Scoggins

Wind is one of the most important atmospheric parameters used in the design of space vehicles. Because it has temporal and spatial variations, the representation of the data in a simple and concise form for design is extremely difficult. For these reasons, caution must be exercised in the employment of wind data to insure consistency with the physical interpretation relative to the specific design problem.

5.0 Definitions

Surface Winds: Winds below a height of 150 meters.

Quasi-Steady-State Wind Speed: A two-minute average of the surface wind speed measured at a fixed height.

Average Wind Speed: An average of the wind speed measured at a fixed height and in general synonymous with the quasi-steady-state wind speed.

Scalar Wind Speed: The magnitude of the wind speed without regard to direction.

Wind Direction: The direction from which the wind is blowing measured clockwise from true North.

Reference Height (Surface Winds): The height above the ground at which wind speeds are referred for purposes of establishing climatological conditions and quasi-steady-state wind speed profiles.

Peak Wind Speed: The maximum wind speed reached during a two-minute interval and obtained by multiplying the quasi-steady-state wind speed by gust factor of 1.4.

Daily Peak Wind Speed: The maximum (essentially instantaneous) wind speed observed during a 24-hour period.

Monthly Peak Wind Speed: Analogous to daily peak wind speed but referred to a monthly period.

Calm Winds: A wind speed of less than one knot (0.5 m/sec).

Windiest Monthly Reference Period: This is any month that has the highest wind speeds at a given probability level.

Gust Factor: The ratio of peak wind speeds to the quasi-steady-state wind speed.

Percentile: The percentage of time that a variable does not exceed a given magnitude.

Wind Shear: The difference between wind speeds measured at two heights divided by the height interval.

Gust: An increase or decrease in the wind speed relative to the quasi-steady-state value.

Free Standing Winds: The surface winds which are applied when the vehicle is standing on the launch pad (with or without fuel) prior to launch and after any service structure or shelter has been removed.

Hurricanes: Severe tropical storms (usually over water) having winds of 64 knots (33m/sec) or greater and covering thousands of square miles of area.

Launch Winds: Maximum surface winds for which the vehicle can be launched.

Inflight Winds: Winds occurring above a height of 150 meters.

Quasi-Steady-State Inflight Wind: The wind speeds as computed by the rawinsonde system which are averaged over approximately 600 meters in the vertical direction.

Wind Speed Change: Difference in the magnitudes of two winds measured at two different heights.

Scale-of-Distance: The vertical distance between two wind measurements used in computing wind shears.

Reference Height (Inflight Winds): The height referred to in constructing a synthetic wind profile.

5.1 Surface Winds

5.1.1 Introduction

In this report surface winds refer to winds below a height of 150 m. Most wind measurements available for the Cape Kennedy area were made at a height of only a few meters. However, the quasi-steady-state (see Sections 5.1.3, 5.1.5, and 5.1.6) wind speeds may be determined with reasonable accuracy from these measurements to a height of 150 meters.

This section presents information on surface winds using available data. Statistics of quasi-steady-state wind speed profiles appear to be well established; but information on gust structure and shears, and interrelationship between shears, gusts, and speeds is incomplete.

Because of local influences, surface winds have characteristics peculiar to the measurement location. The complete specification of surface winds for any of the locations considered in this document is not possible at this time. The 150 m meteorological tower (Ref. 5.1) nearing operational status at Merritt Island Launch Area (MILA) will, hopefully, provide the required data for specifying surface wind conditions for Cape Kennedy. Even though not presented in great detail, the information on surface winds in this section should be sufficient for general design studies. Additional specialized data are available for specific studies.

5.1.2 Measurements

Surface winds are normally measured by instruments called anemometers. There are several anemometers now in general use. The most common being used at the Test Rangers are the Aerovane* and cup types made by Beckman and Whitley, Inc., and Climet Instruments, Inc. The aerovane resembles an airplane in shape with only a propeller and tail fin. It is mounted so that the body and tail act as a wind vane to provide wind direction, while the propeller provides a measure of wind speed. This anemometer has a relatively slow response, measuring only about 50 percent of the amplitudes of gusts with a period of 4 seconds when the mean wind speed is 5 ms^{-1}.

The Beckman and Whitley, and Climet types consist of cups to measure wind speed and a separate vane to measure wind direction. Due to lower inertia, these instruments generally have a better frequency response than the aerovane, indicating about 50 percent of the amplitudes of gusts with a period of 1 second when the mean wind speed is 5 ms^{-1} (Ref. 5.2).

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* Bendix Corp.

When measuring quasi-steady-state wind speeds (defined in this report as a time average over 2 minutes), any of the above anemometers provide adequate data. However, because of their slow responses, they are not suited for resolving frequencies above approximately 1 cycle per second. Most wind measurements available today, and those used in this report to establish quasi-steady-state profiles, are average winds and are adequate for this purpose.

High frequency gusts are usually measured by higher response research oriented anemometers. These anemometers, which are composed of hot wires, sonics, drag spheres, etc., are not commonly used because of operational and other difficulties. The gust data presented in this report were based primarily on measurements from anemometers of the research types. High frequency gust data do not exist in large quantities and are generally available only from the original investigator.

5.1.3 Surface Wind Climatology for The Eastern Test Range (ETR) Florida.

Two-minute time averaged wind measurements discussed in Section 5.1.2 have been employed to describe the surface wind climatology for ETR. Figures 5.1A through 5.1C show the monthly surface wind roses for the period 1950-1959 based on data measured at Patrick Air Force Base once each hour at a height of 23.5 m (Ref. 5.3). These wind roses show the probability of occurrence of wind speeds for sixteen compass points.

Figure 5.2 shows the monthly scalar wind speed* distributions for selected probability levels at the 23.5-meter height (Ref. 5.3.) Excluding the peaks during early summer and fall, which were caused by the thunderstorms and hurricanes, there is little change in wind speed throughout the year for a given probability level. Figures 5.3A and 5.3B show the same probabilities of occurence as in Figure 5.2 of scalar wind speeds as a function of hour of the day for January and July. The wind speeds show little variation with time of day during January, but show a well defined variation during July. This is because of the association between wind speeds and their generating forces. During the winter the pressure gradient is stronger and thermal effects are less pronounced than in the summer. The higher wind conditions during the afternoon in July are caused by thunderstorms and the sea breeze. During early morning hours the atmosphere becomes more stable, the land breeze subsides, and since the pressure gradient is weak, the wind speeds decrease below the winter values.

* Quasi-steady-state values are used in this section except where noted as daily peak values.

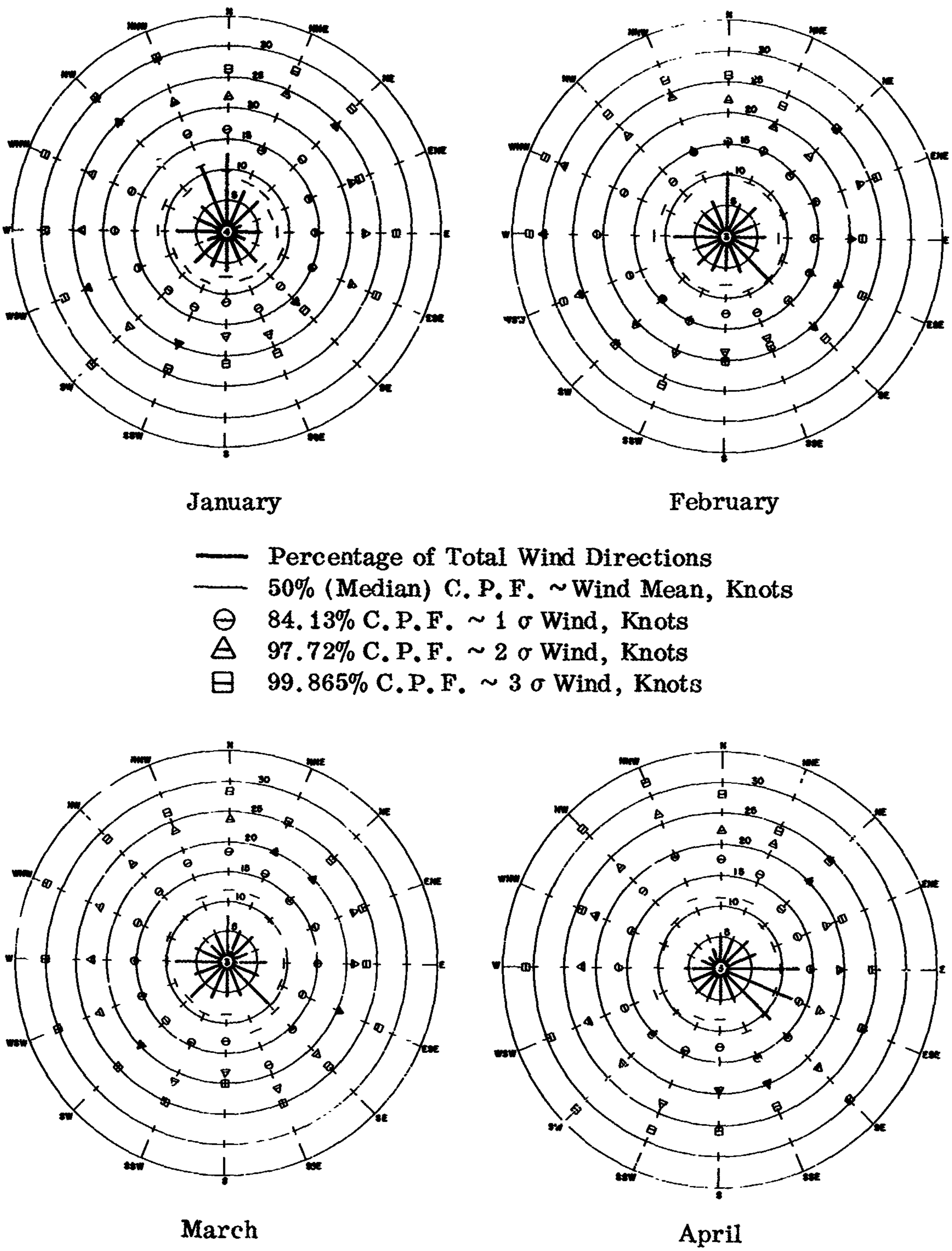
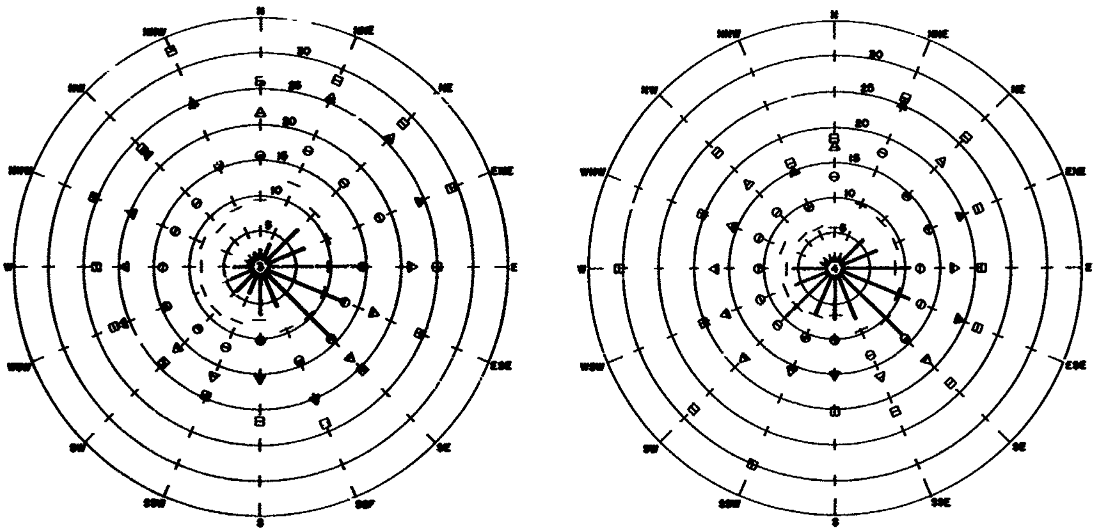
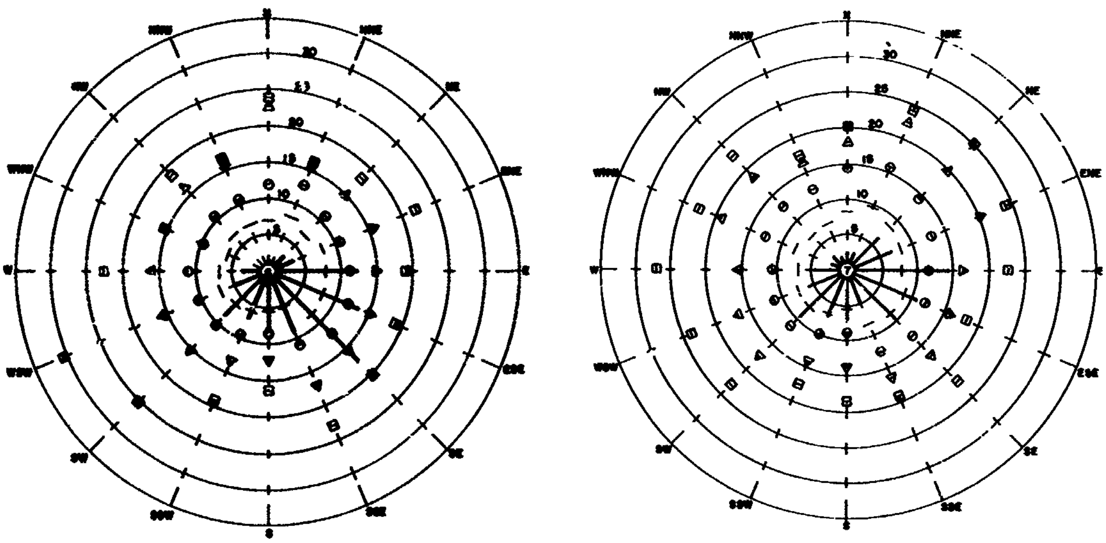


FIGURE 5.1A SURFACE WIND ROSES FOR EASTERN TEST RANGE (PATRICK AFB, FLORIDA) JANUARY TO APRIL REFERENCED HEIGHT 23.5 METERS ABOVE NATURAL GRADE



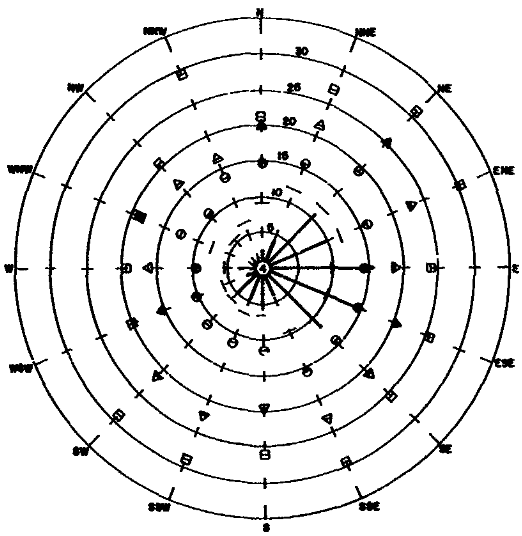
May June

——— Percentage of Total Wind Directions
——— 50% (Median) C.P.F. ~ Wind Mean, Knots
⊖ 84.13% C.P.F. ~ 1 σ Wind, Knots
△ 97.72% C.P.F. ~ 2 σ Wind, Knots
⊟ 99.865% C.P.F. ~ 3 σ Wind, Knots

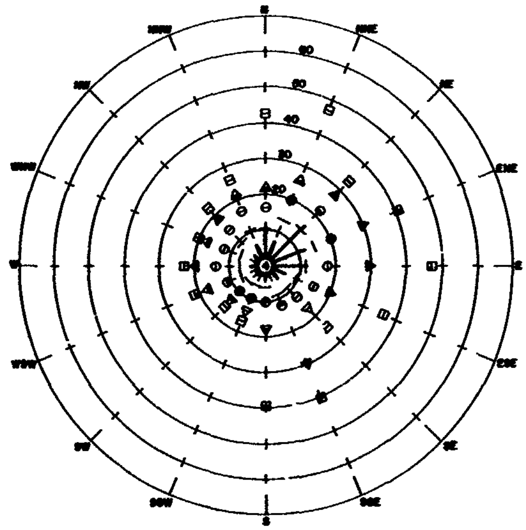


July August

FIGURE 5.1B SURFACE WIND ROSES FOR EASTERN TEST RANGE (PATRICK AFB, FLORIDA) MAY TO AUGUST REFERENCED HEIGHT 23.5 METERS ABOVE NATURAL GRADE

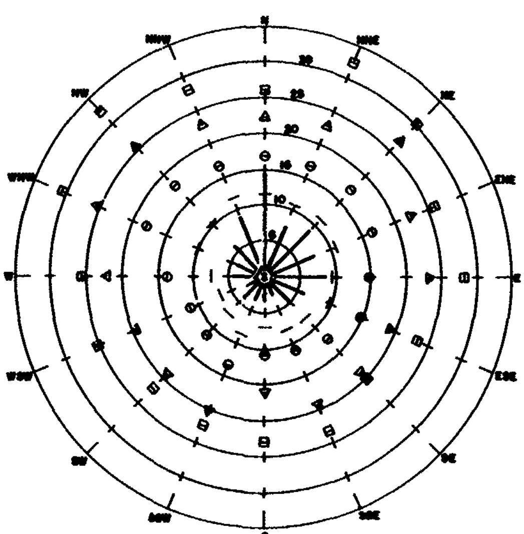


September

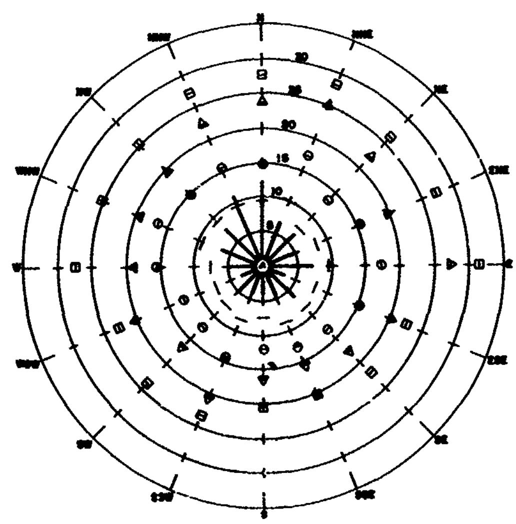


October

———	Percentage of Total Wind Directions
- - -	50% (Median) C. P. F. ~ Wind Mean, Knots
⊖	84.13% C. P. F. ~ 1 σ Wind, Knots
△	97.72% C. P. F. ~ 2 σ Wind, Knots
⊟	99.865% C. P. F. ~ 3 σ Wind, Knots



November



December

FIGURE 5.1C SURFACE WIND ROSES FOR EASTERN TEST RANGE (PATRICK AFB, FLORIDA) SEPTEMBER TO DECEMBER REFERENCED HEIGHT 23.5 METERS ABOVE NATURAL GRADE

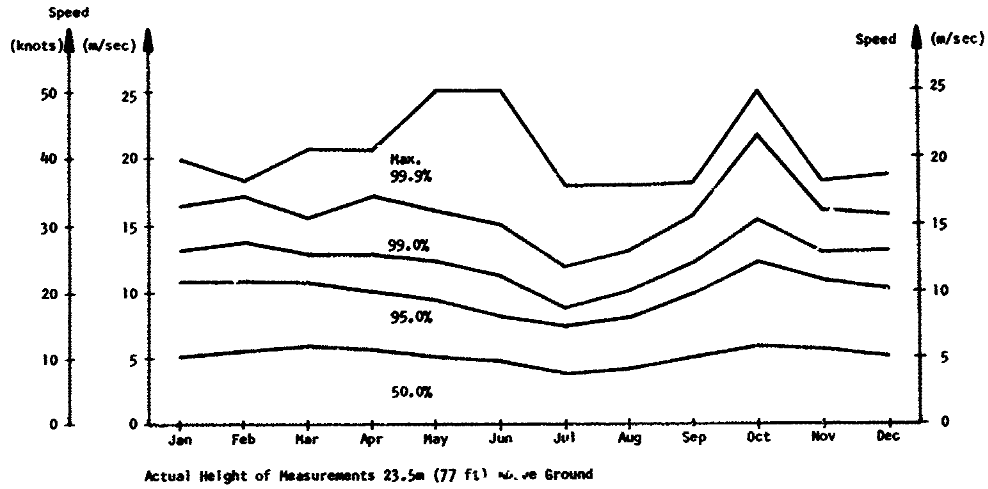


FIGURE 5.2 MONTHLY SCALAR WIND DISTRIBUTION FOR PATRICK AFB

Selected percentile values of daily peak or nearly instantaneous wind speeds for each month, season and annual (Ref. 5.4) for the period February 1950 - January 1964 are shown in Table 5.1 for a reference height of 10 meters (a discussion on determining winds at a given reference height is given in Section 5.1.5). These data are based on a fourteen-year serially complete data sample which combines Cape Kennedy and Patrick Air Force Base observations. The data presented in Table 5.1 show that except for high percentiles, daily peak wind speeds are almost independent of the time of year.

It is frequently desirable to know the probability of exceeding a given wind speed at some reference height. Cumulative percentage frequency (CPF) distributions of quasi-steady-state wind speeds measured at Cape Kennedy over an 8-year period at a height of 9.1 meters (30 feet) are presented in Figures 5.4A through 5.4E. Figure 5.4A represents an envelope of monthly wind speed statistics for the various percentiles. Design values taken from section 5.1.6 are shown in the Figure. Figures 5.4B through 5.4E show CPF's for each month. Hurricane influenced winds have been omitted from the data sample except when noted on the figures. The percentiles given on the abscissa may be interpreted as the percentage of time that the corresponding wind speeds, read from the ordinate, are not exceeded.

The last item to be discussed relating to surface climatology for the ETR area is the frequency of calm winds. Table 5.2 shows the frequency of calm winds at the 10-meter reference height as a function of time of day and month (Ref. 5.3). The maximum percentage of calms appears in the summer and during the early morning hours, with the minimum percentage appearing throughout the year during the afternoon.

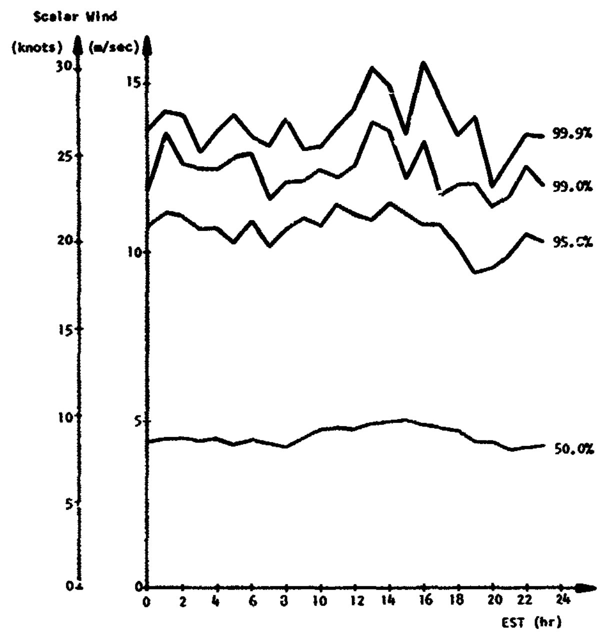


FIGURE 5.3A HOURLY SURFACE SCALAR WIND DISTRIBUTION
FOR PATRICK AFB FOR MONTH OF JANUARY
REFERENCED HEIGHT 23.5 METERS ABOVE NATURAL GRADE

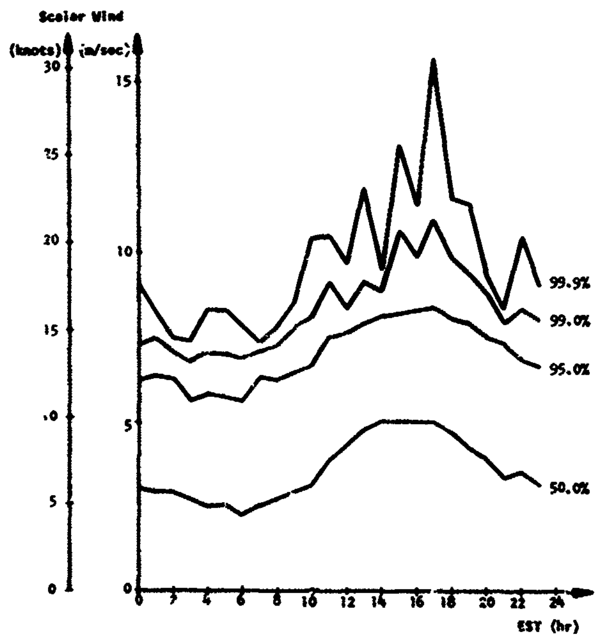


FIGURE 5.3B HOURLY SURFACE SCALAR WIND DISTRIBUTION
FOR PATRICK AFB FOR MONTH OF JULY
REFERENCED HEIGHT 23.5 METERS ABOVE NATURAL GRADE

TABLE 5.1 DAILY PEAK SURFACE WINDS
SELECTED PERCENTILE VALUES (ms^{-1})
CAPE KENNEDY, FLORIDA
FEBRUARY 1950 TO JANUARY 1964
REFERENCE HEIGHT - 10 METERS

Calendar Period	Percentile									
	1	5	10	25	50	75	90	95	99	99.9
January	3.1	4.1	4.6	6.2	8.2	11.3	13.9	16.0	18.5	22.1
February	3.6	4.6	5.1	6.7	8.2	11.3	14.9	17.0	21.1	22.1
March	4.1	5.1	6.2	6.7	8.8	11.3	15.4	17.0	21.1	27.8
April	3.6	5.1	6.2	6.7	8.2	10.8	14.4	16.5	22.1	24.2
May	4.6	5.1	5.7	6.7	8.2	10.3	12.4	15.4	19.0	25.2
June	4.2	5.1	5.7	6.2	7.7	10.3	13.4	16.5	22.1	32.9
July	3.6	4.6	5.1	6.2	7.2	9.8	12.9	16.0	21.6	24.7
August	3.6	4.6	5.1	6.2	7.2	9.8	12.9	14.9	20.6	25.7
September	3.6	4.6	5.1	6.2	7.7	11.3	14.4	18.0	21.1	22.1
October	3.6	4.6	5.1	6.7	8.2	11.8	13.9	16.0	19.0	27.8
November	3.6	4.1	4.6	6.2	7.7	10.3	12.9	14.4	20.6	28.8
December	3.6	4.1	4.6	6.2	7.7	11.3	14.4	16.0	20.6	29.3
Winter	3.1	4.1	5.1	6.2	8.2	11.3	14.4	16.5	20.1	27.3
Spring	4.6	5.1	6.2	6.7	8.2	10.8	13.9	16.5	21.6	26.8
Summer	4.1	4.6	5.1	6.2	7.7	9.8	13.4	16.0	21.6	26.8
Fall	3.6	4.6	5.1	6.2	8.2	11.3	13.4	16.0	21.1	28.8
Annual	3.6	4.6	5.1	6.2	7.7	10.8	13.9	16.5	21.1	28.8

5.1.4 Exposure Period Probabilities.

Figure 5.5 shows annual exposure period probabilities of daily peak wind speeds based on data from Cape Kennedy and Patrick Air Force Base for the period February 1950 to January 1964 (Ref. 5.4). The abscissa represents the number of consecutive days of exposure, with arbitrary origin, that a given magnitude of daily peak surface winds will occur at least once during the period, and the ordinate represents the probability in percent that the daily peak wind speed at the 10-meter reference height will equal or exceed selected values at least once during the exposure periods given on the abscissa. For example, at the point "x" on the figure, there is a 79 percent chance that 12.9 m/sec will be exceeded at least once during any arbitrary 15 day period.

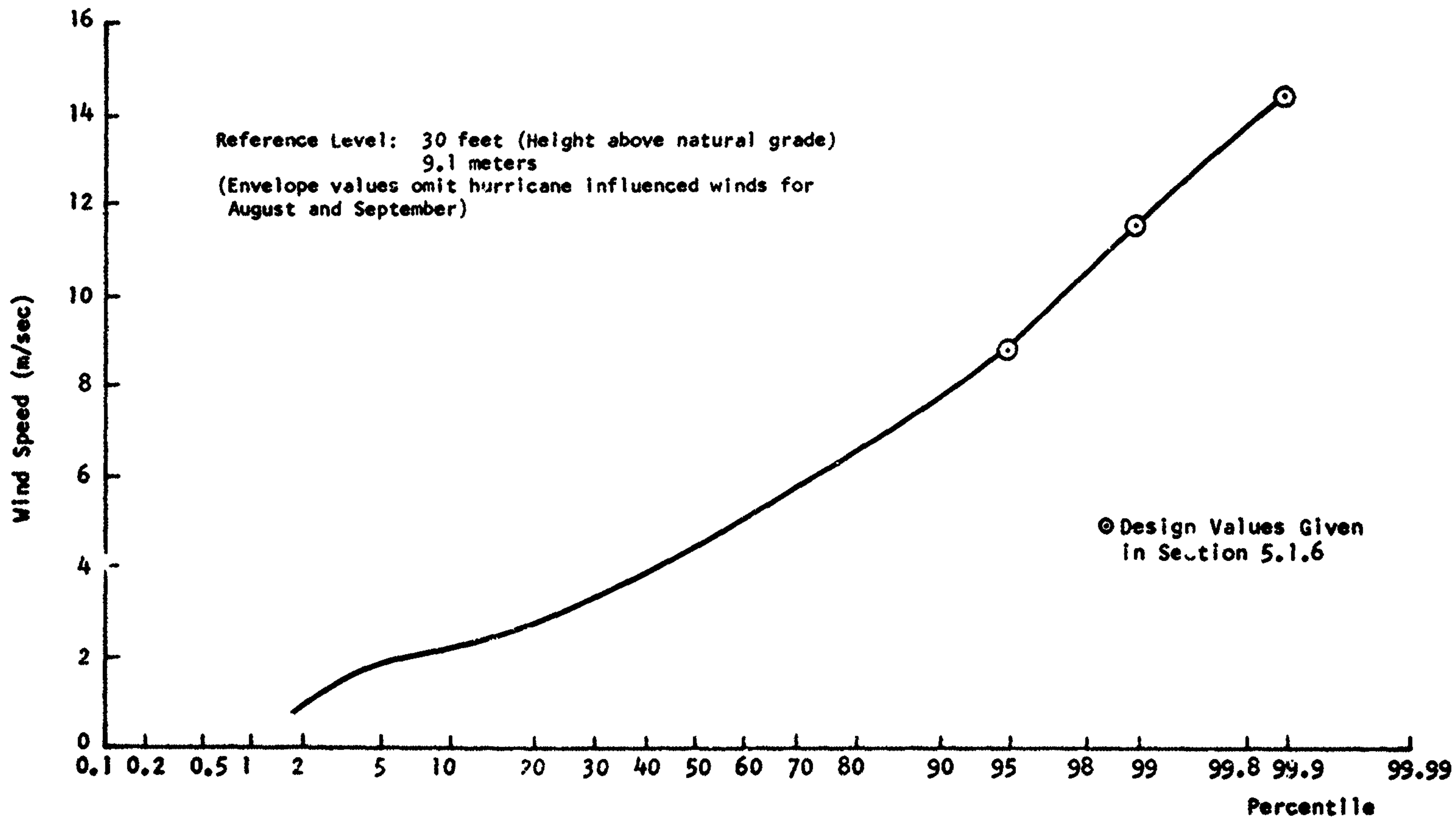


FIGURE 5.4A. WINDIEST MONTHLY REFERENCE PERIOD ENVELOPE OF SURFACE QUASI-STEADY-STATE WIND STATISTICS, CAPE KENNEDY, FLORIDA

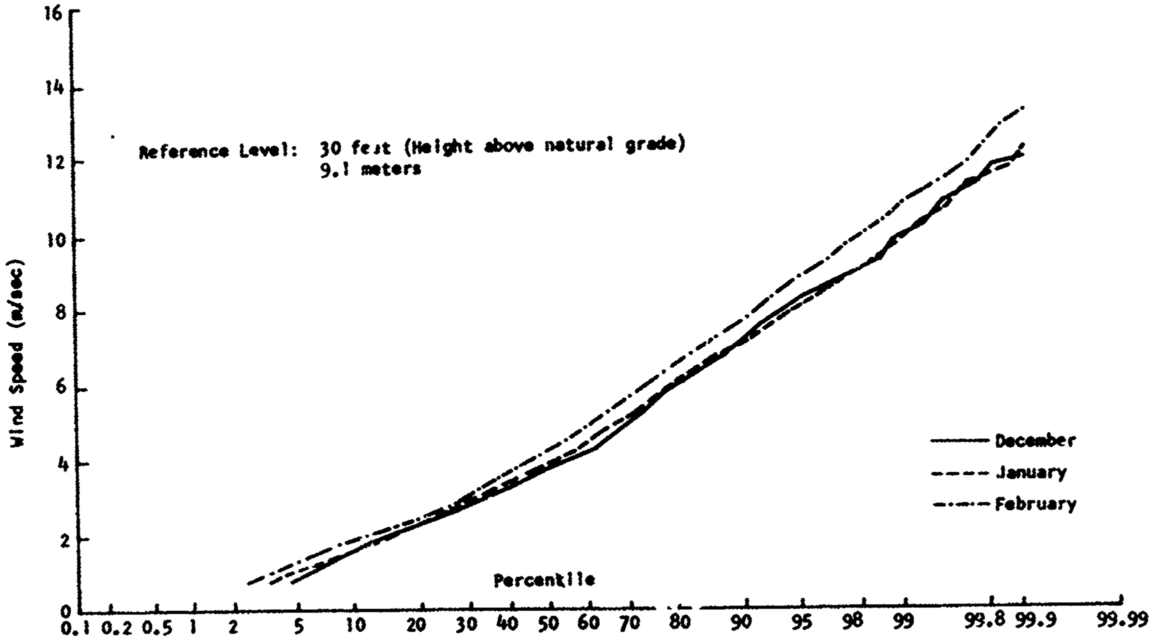


FIGURE 5. 4B MONTHLY CUMULATIVE PERCENTAGE FREQUENCIES OF SURFACE QUASI-STEADY-STATE WIND SPEEDS, CAPE KENNEDY, FLORIDA -- DECEMBER, JANUARY, AND FEBRUARY

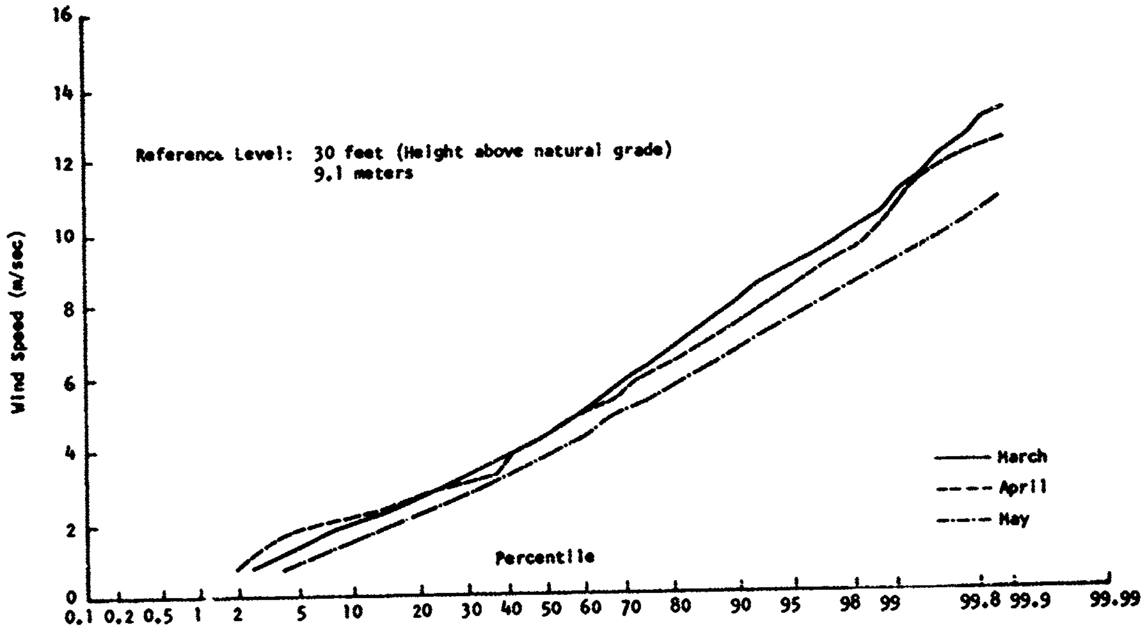


FIGURE 5. 4C MONTHLY CUMULATIVE PERCENTAGE FREQUENCIES OF SURFACE QUASI-STEADY-STATE WIND SPEEDS, CAPE KENNEDY, FLORIDA -- MARCH, APRIL, AND MAY

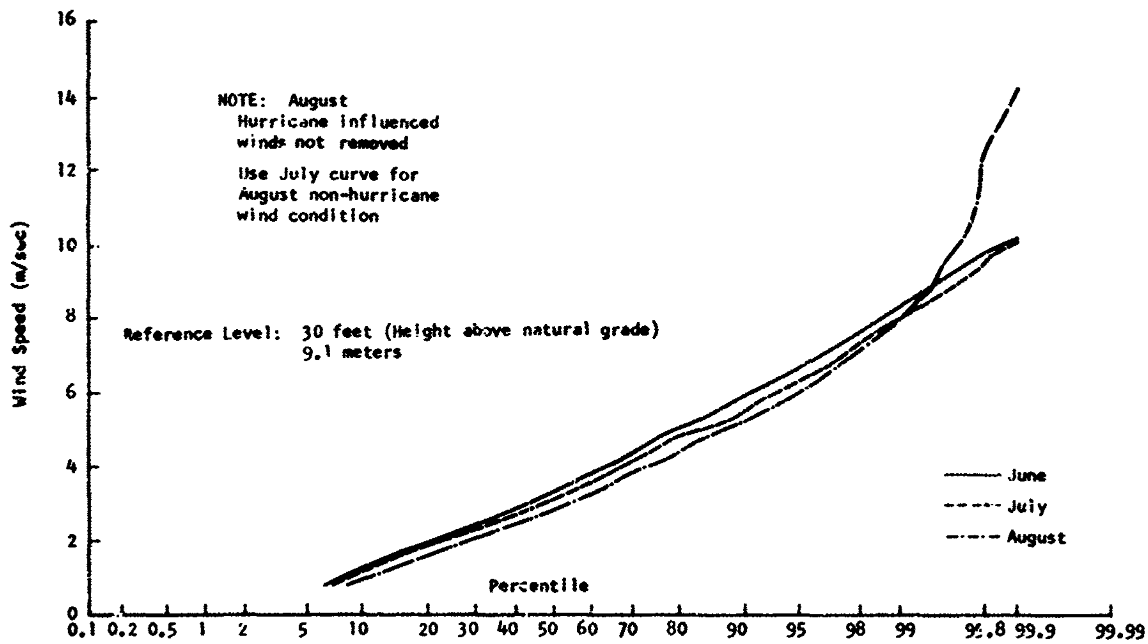


FIGURE 5.4D MONTHLY CUMULATIVE PERCENTAGE FREQUENCIES OF SURFACE QUASI-STEADY-STATE WIND SPEEDS, CAPE KENNEDY, FLORIDA -- JUNE, JULY, AND AUGUST

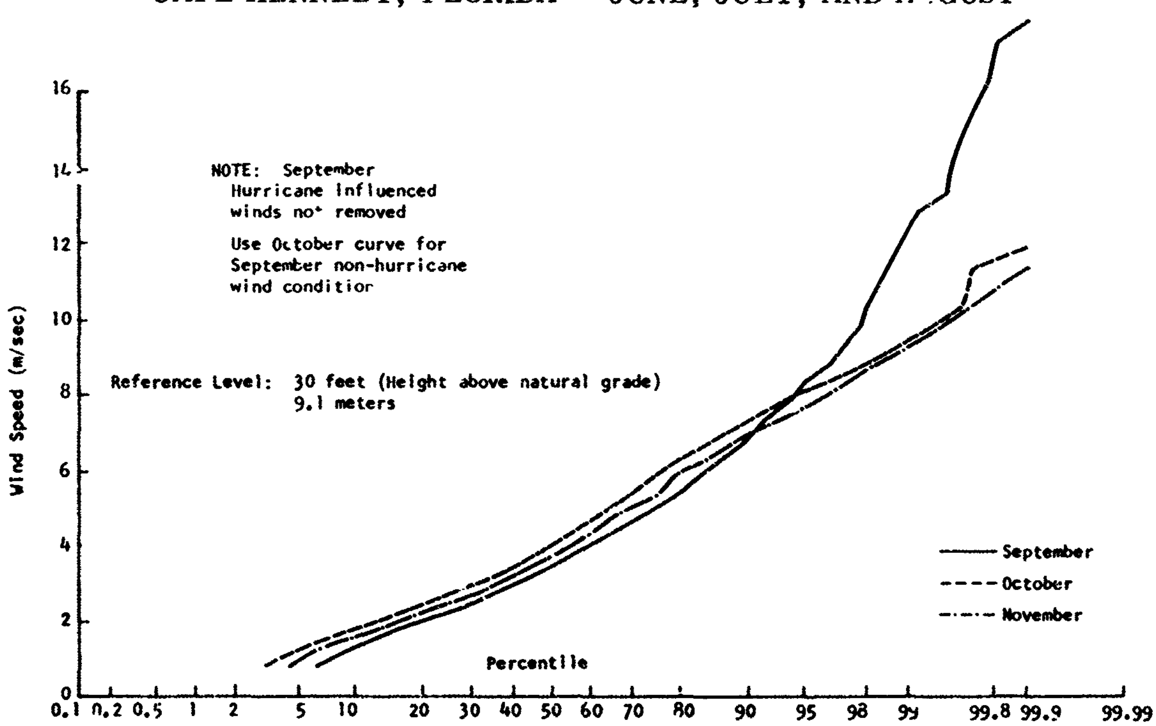


FIGURE 5.4E MONTHLY CUMULATIVE PERCENTAGE FREQUENCIES OF SURFACE QUASI-STEADY-STATE WIND SPEEDS, CAPE KENNEDY, FLORIDA -- SEPTEMBER, OCTOBER, AND NOVEMBER

TABLE 5.2 FREQUENCY (%) OF CALM WIND AT 10-METER LEVEL ABOVE NATURAL GRADE
CAPE KENNEDY, FLORIDA
PERIOD OF RECORD: DEC. 1956 - NOV. 1964

Hour EST	Month												Annual
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
00	4.8	4.0	3.6	1.3	7.3	9.2	11.7	13.7	6.3	6.9	6.3	6.0	6.8
01	2.8	1.3	2.4	1.7	8.9	8.3	10.9	14.1	7.1	4.8	6.3	6.5	6.3
02	4.8	2.2	3.6	2.9	7.7	10.0	11.7	13.7	10.4	7.3	5.4	4.0	7.0
03	5.2	3.1	2.0	3.8	8.5	12.1	11.3	17.3	12.1	5.2	2.9	3.2	7.3
04	2.8	4.4	2.4	3.8	5.2	13.8	14.5	13.7	10.8	5.2	4.6	2.8	7.0
05	4.4	4.0	3.2	2.9	9.7	16.3	15.3	18.5	13.3	3.6	4.6	4.4	8.4
06	4.4	4.0	4.4	2.9	8.9	16.3	19.8	19.0	13.3	3.2	5.0	5.2	8.9
07	3.6	4.4	4.8	6.3	10.5	16.7	18.1	19.4	15.8	4.4	5.4	5.6	9.6
08	3.6	6.6	6.5	2.9	2.4	5.4	6.0	6.9	4.6	4.0	8.8	4.4	5.2
09	3.6	1.8	2.0	2.1	2.8	3.8	4.8	1.6	4.2	0.8	4.6	5.6	3.1
10	0.4	1.8	1.6	1.7	0.4	3.8	4.0	2.8	2.1	*	1.3	2.4	1.8
11	0.4	1.3	1.2	1.7	0.8	1.3	2.4	0.8	2.9	0.8	1.7	0.8	1.3
12	1.6	0.4	*	*	*	0.8	0.8	0.4	1.3	0.4	2.1	1.2	0.8
13	2.0	0.4	*	*	0.4	1.3	0.4	1.6	0.8	0.4	1.7	0.4	0.8
14	0.8	4.0	0.8	0.4	0.4	0.8	1.2	1.6	1.3	0.8	*	0.4	0.7
15	0.4	1.3	*	*	*	0.8	0.4	1.6	2.5	0.4	0.4	0.4	0.7
16	0.4	0.4	0.4	*	0.8	0.4	0.8	0.4	1.3	0.8	*	0.8	0.5
17	1.6	0.4	*	0.4	0.4	2.1	0.8	3.2	2.1	1.6	1.7	2.0	1.4
18	4.0	1.8	0.8	0.4	1.6	2.5	3.2	4.0	2.9	1.2	5.0	7.7	2.9
19	2.8	3.5	2.0	*	1.6	5.0	2.8	5.2	4.6	1.2	7.1	6.5	3.5
20	4.4	3.5	2.8	1.7	3.2	6.7	5.6	8.5	7.5	1.6	6.3	6.0	4.8
21	5.2	4.0	3.2	1.3	4.8	7.5	10.5	8.9	8.3	4.4	5.0	6.0	5.8
22	3.6	2.2	2.4	1.7	6.0	7.5	7.7	12.9	7.9	4.8	6.3	5.2	5.7
23	5.6	3.5	4.8	0.8	6.5	8.3	10.5	15.3	10.0	5.6	4.6	5.2	6.8
All Hours	3.1	2.5	2.3	1.7	4.1	6.7	7.3	8.6	6.4	2.9	4.0	3.9	4.5

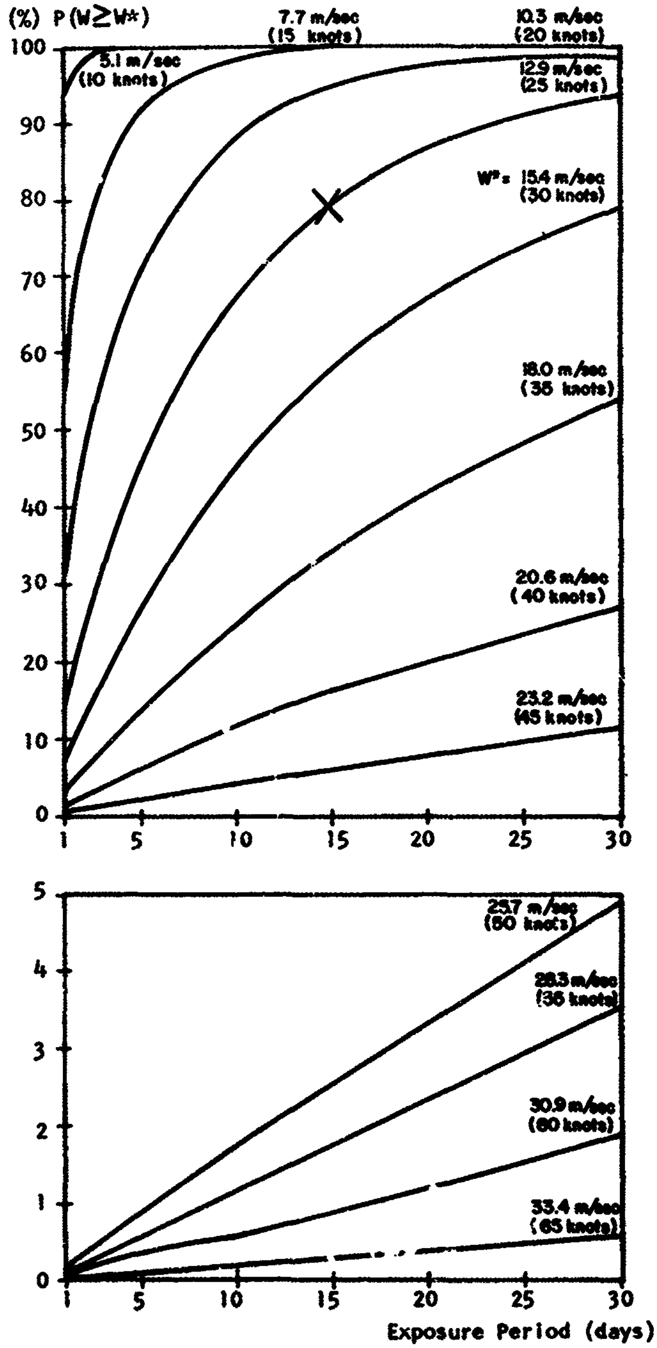


FIGURE 5.5 ANNUAL EXPOSURE PERIOD PROBABILITIES OF DAILY PEAK WIND SPEEDS, CAPE KENNEDY AND PATRICK AIR FORCE BASE, FLORIDA, (5110 OBSERVATIONS) REFERENCE HEIGHT - 10 METERS

5.1.5 Variation of Quasi-Steady-State Wind Speed with Height.

The earth's surface exerts a frictional force on the lower layers of the atmosphere causing a decrease in the average wind speeds near the surface. Assuming that stress is proportional to the square of wind shear, and that the proportionality constant varies linearly with height, the steady-state wind speed profile may be represented by a logarithmic function of height (Ref. 5.5). This representation turns out to be approximately valid during neutral to slightly unstable stability conditions which usually include high wind speeds. An empirical formulation, which approximates the logarithmic function, has been widely used in scientific as well as engineering work. This formulation is called the "power law" and is given by

$$U = U_1 \left(\frac{Z}{Z_1}\right)^p \tag{1}$$

where U is the wind speed at height Z, U_1 is the wind speed at the reference height Z_1, and p is an exponent. Once p is known, the wind speed need only be measured at the reference height to define the entire profile to a height of about 150 meters.

The exponent p is a function of wind speed, ground roughness, etc. and increases as the wind speed decreases. For moderate ground roughness conditions, such as exist at Cape Kennedy, and during high wind speeds, the value of p is usually 0.2 or less. For design purposes, a value for p of 0.20 is employed when the three-meter height steady-state wind speed is between 7 and 15 m/s^{-1} and a value for p of 0.14 is used when the steady-state wind speed is between 22 and 30 m/s^{-1}. The above values of p are the only values used in this report. These specific values are specified to avoid ambiguities in reading values from graphs of data in this report.

Using the power law profile, wind measurements at any height may be tranformed (referred) to any other height. This is frequently done when measurements are made at different locations and heights so that statistical values for wind measurements can be combined or comparisons made. This was done for data measured at Patrick Air Force Base and Cape Kennedy for some of the results presented in this report and to establish the design envelopes of wind speeds for various percentages values. The power law profile is usually considered valid below a height of approximately 150 meters.

5.1.6 Quasi-Steady-State Wind Speed Profiles for Various Locations.

The data presented in this section provide basic wind speed profile (envelope) information for use in studies to determine load factors

for test, free standing, launch, and lift-off conditions to insure satisfactory performance of the space vehicle. To establish vehicle design requirements, the surface winds are assumed to act normal to the longitudinal axis of the vehicle on the launch pad and to be from the most critical direction. The quasi-steady-state and peak wind speeds with reference to the windiest monthly reference period for various locations are given in Tables 5.3A through 5.8B (Refs. 5.6, 5.7, 5.8, 5.9, and 5.3). Reference 5.3 should be consulted for additional surface wind speed and direction information for Cape Kennedy, Florida (Eastern Test Range). For specific design problems, data for other percentile levels are available.

To establish these wind speed envelopes, all available hourly surface quasi-steady-state wind speed (2-minute average) data were reduced to a common reference height, as described in section 5.1.5, and a statistical analysis was made of the data to determine the percentile values. Statistical envelope values of the quasi-steady-state wind speeds for other heights were determined by use of the power law equation. Values of peak wind speed were obtained by multiplying the steady-state wind speeds by a gust factor of 1.4. The daily peak wind at Cape Kennedy, Florida, discussed in section 5.1.3, differs from the windiest monthly reference period peak winds given in this section because the two data samples are different in terms of reference period, type, and basic data content. The values given in this section are for monthly reference periods and are frequently used in design studies for the specific locations noted when the question of exposure period or pad stay time is in the order of a few hours. When the pad stay time is extensive, i.e., days or weeks, then Reference 5.4 should be consulted relative to potential operational risks for the Cape Kennedy, Florida area. Additional data on this subject for specific design or operational problems are available upon request.

Due to the complex nature of surface wind fluctuations as a function of terrain features, etc., the values given for the surface wind speed envelopes at the various locations are considered to be representative values only. They represent a common reference source for wind data from which approximate load factors may be determined on a comparative basis by various design organizations. The tables provide only statistical design envelopes for given percentiles and are not meant to imply a perfect correlation of speeds over the heights shown. Furthermore, the tables represent the statistical probability of wind speeds not being exceeded based on individual hourly observations. Tables 5.3A through 5.8B were prepared with respect to the windiest monthly reference period.

TABLE 5.3A SURFACE WIND SPEED ENVELOPES 99 PERCENTILE FOR HUNTSVILLE

Height Above Ground		Quasi-Steady-State Wind		Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)	(ms^{-1})	(knots)
3.0	10	10.3	20.1	14.5	28.1
9.1	30	12.9	25.0	18.0	35.0
18.3	60	14.8	28.8	20.7	40.3
30.5	100	16.4	31.9	23.0	44.7
61.0	200	18.8	36.6	26.3	51.2
91.4	300	20.4	39.7	28.6	55.6
121.9	400	21.6	42.0	30.2	58.8
152.4	500	22.6	44.0	31.7	61.6

TABLE 5.3B SURFACE WIND SPEED ENVELOPES 99.9 PERCENTILE FOR HUNTSVILLE

Height Above Natural Grade		Quasi-Steady-State Wind		Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)	(ms^{-1})	(knots)
3.0	10	12.4	24.1	17.3	33.7
9.1	30	15.4	30.0	21.6	42.0
18.3	60	17.7	34.5	24.8	48.3
30.5	100	19.7	38.2	27.5	53.5
61.0	200	22.6	43.9	31.6	61.5
91.4	300	24.5	47.6	34.3	66.6
121.9	400	25.9	50.4	36.3	70.6
152.4	500	27.1	52.7	38.0	73.8

TABLE 5.4A SURFACE WIND SPEED ENVELOPES 99 PERCENTILE FOR NEW ORLEANS, RIVER TRANSPORTATION, GULF TRANSPORTATION, AND PANAMA CANAL TRANSPORTATION

Height Above Natural Grade		Quasi-Steady-State Wind		Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)	(ms^{-1})	(knots)
3.0	10	9.5	18.5	13.3	25.9
9.1	30	11.8	23.0	16.6	32.2
18.3	60	13.6	26.5	19.1	37.1
30.5	100	15.1	29.3	21.1	41.0
61.0	200	17.3	33.7	24.3	47.2
91.4	300	18.8	36.5	26.3	51.1
121.9	400	19.9	38.7	27.9	54.2
152.4	500	20.8	40.5	29.2	56.7

TABLE 5.4B SURFACE WIND SPEED ENVELOPES 99.9 PERCENTILE FOR NEW ORLEANS, RIVER TRANSPORTATION, GULF TRANSPORTATION, AND PANAMA CANAL TRANSPORTATION

Height Above Natural Grade		Quasi-Steady-State Wind		Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)	(ms^{-1})	(knots)
3.0	10	13.4	26.1	18.8	36.5
9.1	30	16.7	32.5	23.4	45.5
18.3	60	19.2	37.4	27.0	52.4
30.5	100	21.3	41.4	29.8	58.0
61.0	200	24.4	47.5	34.2	66.5
91.4	300	26.5	51.6	37.1	72.2
121.9	400	28.1	54.6	39.3	76.4
152.4	500	29.4	57.1	41.1	79.9

TABLE 5.5A SURFACE WIND SPEED ENVELOPES 95 PERCENTILE FOR WESTERN TEST RANGE, WEST COAST TRANSPORTATION, AND SACRAMENTO

Height Above Natural Grade		Quasi-Steady-State Wind		Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)	(ms^{-1})	(knots)
3.0	10	8.2	16.0	11.5	22.4
9.1	30	10.2	19.9	14.4	27.9
18.3	60	11.8	22.9	16.5	32.1
30.5	100	13.1	25.4	18.3	35.6
61.0	200	15.0	29.1	20.9	40.7
91.4	300	16.3	31.6	22.7	44.2
121.9	400	17.2	33.5	24.1	46.9
152.4	500	18.0	35.0	25.2	49.0

TABLE 5.5B SURFACE WIND SPEED ENVELOPES 99 PERCENTILE FOR WESTERN TEST RANGE, WEST COAST TRANSPORTATION, AND SACRAMENTO

Height Above Natural Grade		Quasi-Steady-State Wind		Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)	(ms^{-1})	(knots)
3.0	10	10.3	20.0	14.4	28.0
9.1	30	12.8	24.9	18.0	34.9
18.3	60	14.7	28.6	20.6	40.0
30.5	100	16.3	31.7	22.8	44.4
61.0	200	18.7	36.4	26.2	51.0
91.4	300	20.3	39.5	28.4	55.3
121.9	400	21.5	41.8	30.1	58.5
152.4	500	22.5	43.7	31.5	61.2

TABLE 5.6A SURFACE WIND SPEED ENVELOPES 95 PERCENTILE* FOR EASTERN TEST RANGE

Height Above Natural Grade		Quasi-Steady-State Wind		Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)	(ms^{-1})	(knots)
3.0	10	7.2	14.0	10.1	19.6
9.1	30	9.0	17.4	12.6	24.4
18.3	60	10.3	20.0	14.4	28.0
30.5	100	11.4	22.2	16.0	31.1
61.0	200	13.1	25.5	18.4	35.7
91.4	300	14.2	27.6	19.9	38.6
121.9	400	15.1	29.3	21.1	41.0
152.4	500	15.7	30.6	22.0	42.8

* The 95 percentile winds are, in general, exceeded during heavy rain showers, thunderstorms in the area or over the site, squall lines, some frontal passages, strong pressure gradients, and hurricanes.

TABLE 5.6B SURFACE WIND SPEED ENVELOPES 99 PERCENTILE* FOR EASTERN TEST RANGE

Height Above Natural Grade		Quasi-Steady-State Wind		Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)	(ms^{-1})	(knots)
3.0	10	9.5	18.4	13.3	25.8
9.1	30	11.8	22.9	16.5	32.1
18.3	60	13.5	26.3	18.9	36.8
30.5	100	15.0	29.2	21.0	40.9
61.0	200	17.2	33.5	24.1	46.9
91.4	300	18.7	36.3	26.1	50.8
121.9	400	19.8	38.5	27.7	53.9
152.4	500	20.7	40.2	29.0	56.3

* The 99 percentile winds are, in general, exceeded during thunderstorms over the site, squall lines, occasional frontal passages and hurricanes.

TABLE 5.6C SURFACE WIND SPEED ENVELOPES 99.9 PERCENTILE** FOR EASTERN TEST RANGE

Height Above Natural Grade		Quasi-Steady-State Wind		Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)	(ms^{-1})	(knots)
3.0	10	11.8	23.0	16.6	32.2
9.1	30	14.8	28.7	20.7	40.2
18.3	60	16.9	32.9	23.7	46.1
30.5	100	18.8	36.5	26.3	51.1
61.0	200	21.6	41.9	30.2	58.7
91.4	300	23.4	45.4	32.7	63.6
121.9	400	24.7	48.1	34.6	67.3
152.4	500	25.9	50.3	36.2	70.4

** The 99.9 percentile winds are, in general, exceeded during heavy thunderstorms, severe squall lines, and hu[illegible]canes

TABLE 5.7A SURFACE WIND SPEED ENVELOPES 95 PERCENTILE FOR WALLOPS TEST RANGE

Height Above Natural Grade		Quasi-Steady-State Wind		Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)	(ms^{-1})	(knots)
3.0	10	8.9	17.3	12.4	24.2
9.1	30	11.1	21.6	15.5	30.2
18.3	60	12.8	24.8	17.8	34.7
30.5	100	14.1	27.4	19.8	38.4
61.0	200	16.2	31.5	22.7	44.1
91.4	300	17.6	34.2	24.6	47.9
121.9	400	18.6	36.2	26.1	50.7
152.4	500	19.4	37.8	27.2	52.9

TABLE 5.7B SURFACE WIND SPEED ENVELOPES 99 PERCENTILE FOR WALLOPS TEST RANGE

Height Above Natural Grade		Quasi-Steady-State Wind		Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)	(ms^{-1})	(knots)
3.0	10	11.2	21.8	15.7	30.5
9.1	30	14.0	27.2	19.6	38.1
18.3	60	16.0	31.2	22.5	43.7
30.5	100	17.8	34.6	24.9	48.4
61.0	200	20.4	39.7	28.6	55.6
91.4	300	22.1	43.0	31.0	30.2
121.9	400	23.5	45.6	32.8	63.8
152.4	500	24.5	47.7	34.4	66.8

TABLE 5.8A SURFACE WIND SPEED ENVELOPES 95 PERCENTILE FOR WHITE SANDS MISSILE RANGE

Height Above Natural Grade		Quasi-Steady-State Wind		Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)	(ms^{-1})	(knots)
3.0	10	9.7	18.8	13.5	26.3
9.1	30	12.0	23.4	16.9	32.8
18.3	60	13.8	26.9	19.4	37.7
30.5	100	15.3	29.8	21.5	41.7
61.0	200	17.6	34.2	24.6	47.9
91.4	300	19.1	37.1	26.7	51.9
121.9	400	20.2	39.3	28.3	55.0
152.4	500	21.1	41.1	29.6	57.5

TABLE 5.8B SURFACE WIND SPEED ENVELOPES 99 PERCENTILE FOR WHITE SANDS MISSILE RANGE

Height Above Natural Grade		Quasi-Steady-State Wind		Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)	(ms^{-1})	(knots)
3.0	10	12.4	24.1	17.3	33.7
9.1	30	15.4	30.0	21.6	42.0
18.3	60	17.7	34.5	24.8	48.3
30.5	100	19.7	38.2	27.5	53.5
61.0	200	22.6	43.9	31.6	61.5
91.4	300	24.5	47.6	34.3	66.6
121.9	400	25.9	50.4	36.3	70.6
152.4	500	27.1	52.7	38.0	73.8

5.1.7 Wind Direction Characteristics.

Wind direction climatology is shown in Section 5.1.3, Figures 5.1A through 5.1C. The solid lines radiating outward from the center of each wind rose give the percentage of time the wind blows from a given direction. These data show the influence of large-scale or synoptic influences on the statistical variations in wind direction in the Cape Kennedy area. They do not provide information on variations in wind direction over specified periods of time.

Figure 5.6 shows a time trace of wind direction. This wind direction trace may be visualized as being composed of a mean wind direction plus fluctuations about the mean. An accurate measure of wind direction in the free atmosphere near the ground is difficult to obtain because of the interference of the structure which supports the instrumentation and other obstacles in the vicinity of the measurement location. The measured wind directions represent conditions existing at a given place, and may provide the information needed for use in vehicle-response-to-ground-winds studies. Unfortunately, there is not much information available on wind direction fluctuations suitable for presentation here that would contribute to the vehicle response problem. General information is available which may be used to specify conditions for particular studies. A

thorough investigation of wind direction fluctuations is planned when data become available from the 150-meter meteorological tower facility now nearing completion on Merritt Island, NASA, Kennedy Space Flight Center, Flordia.

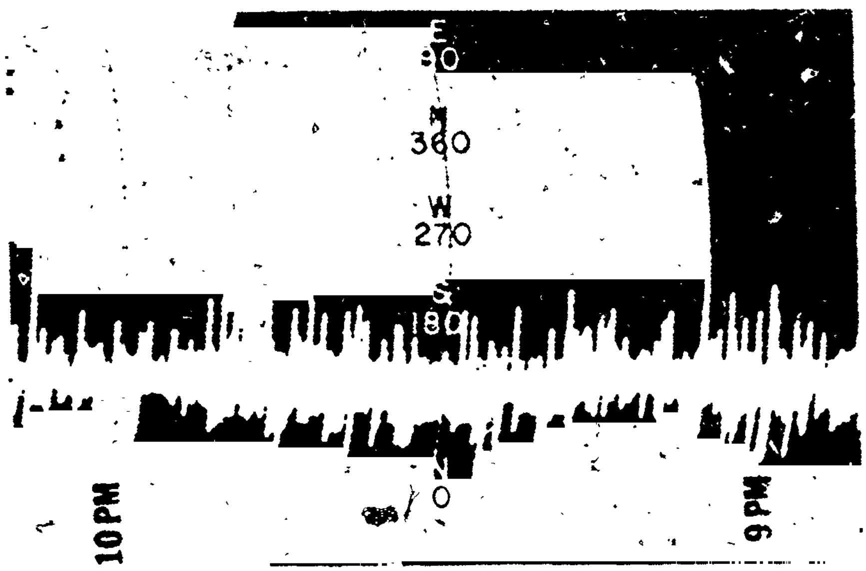


FIGURE 5.6 TYPICAL TRACE OF WIND DIRECTION

5.1.8 Wind Shear.

Wind shear near the surface, for design purposes, is a shear which acts on a space vehicle free-standing on the pad or at time of lift-off. This shear is computed from the selected design percentile wind speed envelope by using the peak wind speed at the top of the vehicle and the quasi-steady-state wind speed at the base of the vehicle with respect to height of the base above the ground. In some cases the base of the vehicle will be elevated some distance above the launch pad or ground level (natural grade).

5.1.9 Gusts.

The gust shape for the higher surface wind conditions given in the tables of Section 5.1.6 is represented by a wedge with linear increase to the peak wind in two seconds and then linear decay to the steady state in two seconds. The gust factor is known to be a function of the steady state wind speed, time average of the wind speed, stability conditions, terrain features, and height.

For purposes of this report, a gust factor of 1.4 has been used to obtain the design peak wind speed. Extensive information on discrete short period gust shapes is not available, probably because of measurement difficulties discussed in section 5.1.2. The gust shape described above is based on limited measurements from fast response anemometers. Again, the 150-meter meteorological tower data are expected to provide valuable information on gust structure.

5.1.10 Spectra of Turbulence.

Considerable interest exists in the use of random process theory to evaluate the influence of winds on free standing space vehicles and other structures. The spectra of turbulence in the x, y, and z directions, in general, differ from one another and vary with wind direction. Suitable measurements have not been available from ETR from which turbulence spectra could be computed. Spectra will be computed from the 150-meter meteorological tower data and published for use in vehicle studies. In the meantime if spectra are required for a specific problem, it is suggested that the Aerospace Environment Division be contacted.

5.1.11 Ground Winds for Facilities Design.

The maximum peak surface wind expected over a number of years is usually employed in design studies relating to buildings, towers, and similar structures. The maximum peak surface wind is the highest wind expected including hurricane and severe thunderstorm conditions, but excluding tornadoes. In order to objectively determine a value of the expected maximum peak surface wind speed for the various heights, the power law was used. Maximum peak wind conditions for a 20-year return period (average number of years during which a single occurrence may be expected) are shown in Tables 5.8C through 5.8H for various locations.

TABLE 5.8C SURFACE WIND SPEED ENVELOPES (MAXIMUM PEAK) FOR HUNTSVILLE

Height Above Natural Grade		Maximum Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)
3.0	10	32.2	62.5
9.1	30	37.4	72.8
18.3	60	41.3	80.3
30.5	100	44.3	86.2
61.0	200	48.9	95.0
91.4	300	51.7	100.6
121.9	400	53.9	104.7
152.4	500	55.6	108.0

TABLE 5.8D SURFACE WIND SPEED ENVELOPES (MAXIMUM PEAK) FOR EASTERN TEST RANGE

Height Above Natural Grade		Maximum Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)
3.0	10	36.5	71.0
9.1	30	42.6	82.8
18.3	60	46.9	91.2
30.5	100	50.4	98.0
61.0	200	55.6	108.0
91.4	300	58.8	114.3
121.9	400	61.2	119.0
152.4	500	63.2	122.8

TABLE 5.8E SURFACE WIND SPEED ENVELOPES (MAXIMUM PEAK) FOR WHITE SANDS MISSILE RANGE

Height Above Natural Grade		Maximum Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)
3.0	10	37.2	72.3
9.1	30	43.4	84.3
18.3	60	47.8	92.9
30.5	100	51.3	99.8
61.0	200	56.6	110.0
91.4	300	59.9	116.4
121.9	400	62.3	121.2
152.4	500	64.4	125.1

TABLE 5.8F SURFACE WIND SPEED ENVELOPES (MAXIMUM PEAK) FOR WESTERN TEST RANGE, WEST COAST TRANSPORTATION, AND SACRAMENTO

Height Above Natural Grade		Maximum Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)
3.0	10	30.5	59.2
9.1	30	35.5	69.0
18.3	60	39.1	76.0
30.5	100	42.0	81.7
61.0	200	46.3	90.0
91.4	300	49.0	95.3
121.9	400	51.0	99.2
152.4	500	52.6	102.3

TABLE 5.8G SURFACE WIND SPEED ENVELOPES (MAXIMUM PEAK) FOR NEW ORLEANS, RIVER TRANSPORTATION, GULF TRANSPORTATION, AND PANAMA CANAL TRANSPORTATION

Height Above Natural Grade		Maximum Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)
3.0	10	37.6	73.0
9.1	30	43.8	85.1
18.3	60	48.3	93.0
30.5	100	51.8	100.7
61.0	200	57.1	111.0
91.4	300	60.4	117.5
121.9	400	62.9	122.3
152.4	500	64.9	126.2

TABLE 5.8H SURFACE WIND SPEED ENVELOPES (MAXIMUM PEAK) FOR WALLOPS TEST RANGE

Height Above Natural Grade		Maximum Peak Wind	
(m)	(ft)	(ms^{-1})	(knots)
3.0	10	40.6	78.9
9.1	30	47.3	92.0
18.3	60	52.2	101.4
30.5	100	56.0	108.9
61.0	200	61.7	120.0
91.4	300	65.3	127.0
121.9	400	68.0	132.2
152.4	500	70.2	136.4

5.2 Inflight Winds

5.2.1 Introduction

Inflight winds are presented and used in many ways in design and operational studies relating to space vehicles. Representing appropriate observed features of the wind field in a relatively simple way for engineering applications is a complex problem. A wind model, even if one could be developed, complex and comprehensive enough to account for all important features of the wind field in combination, would be too complex to apply to engineering problems. On the other hand, a wind model which is too simple may not account for even the most important features. Therefore, a model somewhere between these two extremes must be used and engineering judgment applied to account for shortcomings in the model.

The wind information presented in this section is, in effect, a wind model of modest complexity which incorporates quasi-steady-state wind speeds, wind shears, gusts, and small-scale motions. The combination of these parameters is based on measured data, experience, scientific knowledge, and engineering judgment. As time goes on, more and better data results from scientific investigations, etc., will, no doubt, indicate that changes in the

model should be made. If this is the case, changes will be made as deemed appropriate. However, it does not appear that major revisions to the model will be required in the near future.

5.2.2 Measurements

Wind velocity profiles are measured systematically in this country by two methods, the FPS-16 radar/Jimsphere and the rawinsonde (GMD). The latter is employed extensively throughout the United States and by the Armed Forces, while the former is employed primarily at the Eastern and Western Test Ranges.

5.2.2.1 Rawinsonde (GMD)

This system provides measurements of horizontal wind speed and direction as a function of altitude averaged over approximately 600 meters. Approximate RMS errors in wind speed, based on standard data reduction procedures, vary between approximately 2 and 15 ms^{-1} depending upon wind conditions and tracking geometry; RMS errors in wind direction are estimated to vary between approximately 5 and 20 degrees.

Large quantities of data measured by this system at ETR and at many locations throughout the United States are available. The ETR rawinsonde data have been used extensively in investigating wind conditions at that location, and for specifying wind conditions for use in numerous space vehicle design studies. Because of smoothing inherent in the rawinsonde system, it cannot provide measurements of the small-scale wind motions which may be important in some space vehicle problems. However, serial complete edited and checked master rawinsonde wind data records have been prepared covering an eight-year period for Cape Kennedy, Florida and a nine-year period for Santa Monica, California. These records constitute the source of statistical quasi-steady-state upper air wind statistics used in this document, unless otherwise noted.

5.2.2.2 FPS-16 Radar/Jimsphere

This system provides considerably more accurate wind velocity profile data than does the rawinsonde. The measurements are averaged over 25 to 50 meters in the vertical with an RMS error in wind speed of approximately 0.5 ms^{-1} and 1 degree in wind direction (Ref. 5.10). Thus the FPS-16 radar/Jimsphere wind profile data contain information on small-scale motions as well as gross motions such as provided by the rawinsonde. Approximately one year of profile data measured twice daily, and in support of space vehicle launchings and special studies are available. Some of these data have been published (Ref. 5.11) and a master magnetic tape prepared for ready access.

In addition, a number of studies have been conducted using these improved wind data.

5.2.3 Winds Aloft Climatology.

The subject of wind climatology for any area, if treated in detail, would make up a voluminous document. The intent here is to give a brief treatment of selected topics for the Eastern Test Range which are frequently considered in space vehicle development and operations problems. For additional information on the limited topics covered, or topics not covered at all, the Aerospace Environment Division should be contacted.

5.2.3.1 General Climatology

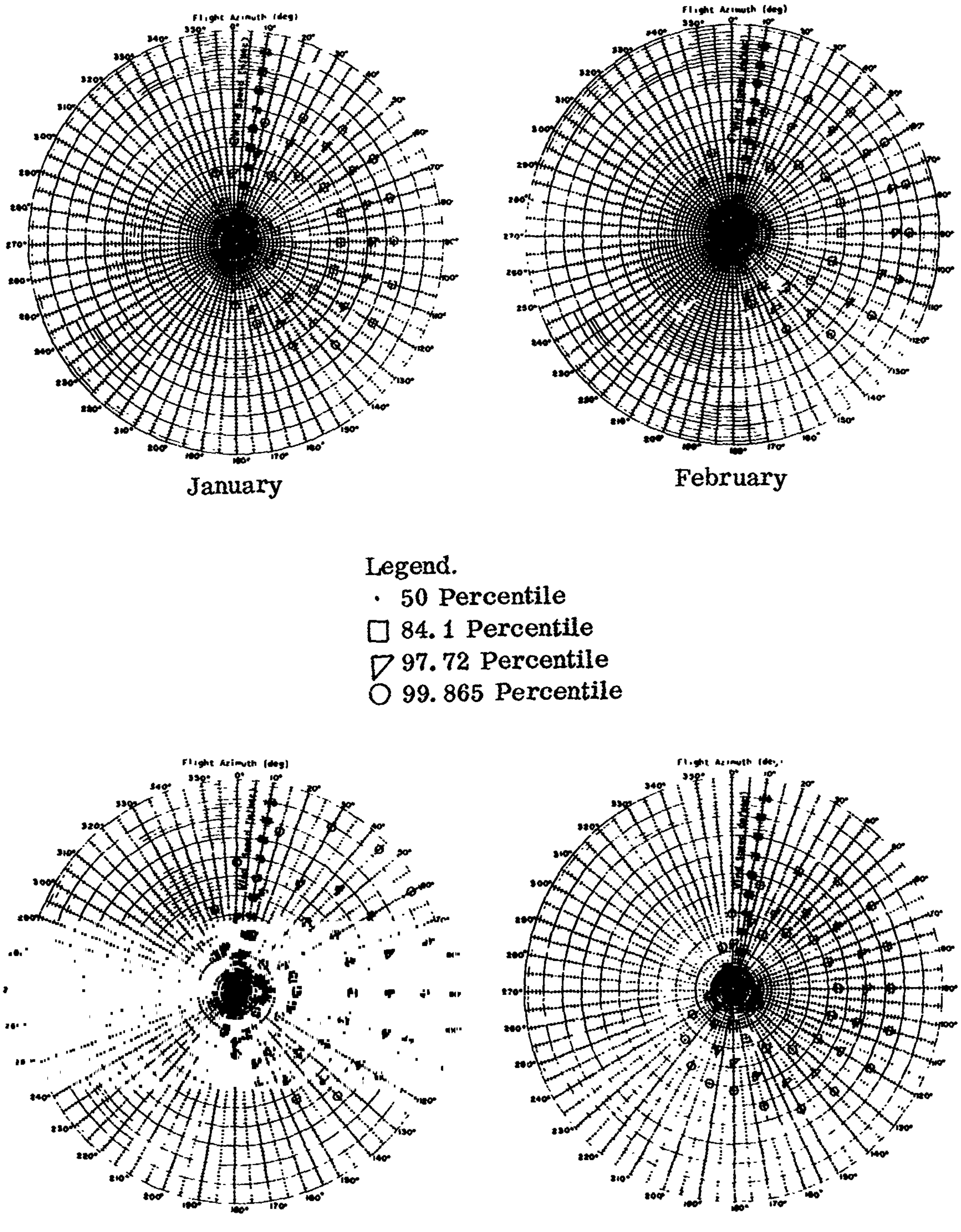
Figures 5.7A through 5.7C show the distribution of wind speeds for several percentiles as a function of wind direction at 12 km altitude for each month of the year. Before interpreting this figure, the plotting procedure should be understood.

Wind velocity is reported as a speed and a direction from which the wind is blowing. In usual vector notation a horizontal wind blowing from 270 degrees would be represented by a vector with its origin at the intersection of the two horizontal axes and pointing toward 90 degrees with a length proportional to the wind speed. Figure 5.7 was plotted using this convention. Strictly speaking, Figure 5.7 is not a vector diagram, but is usually thought of as representing vector components in the pitch and yaw planes.

To illustrate the use of Figure 5.7, consider a launch azimuth of 90 degrees during the month of January. Reading from Figure 5.7A, the 97.72 percentile wind values are tail 74 ms^{-1}; head near zero; right cross 37 ms^{-1}; and left cross 23 ms^{-1}. Wind components for any percentile and launch azimuth may be found analogously.

Plots similar to Figure 5.7 are available from 1 to 27 km altitude, but are too voluminous to include in this document. Figure 5.7 and the component wind speed profiles presented in Section 5.2.5 should be sufficient for most problems encountered at the Eastern Test Range when such information is required.

Figure 5.8 gives envelopes of wind speeds for various percentiles for the Western Test Range (Santa Monica, Calif.). In contrast to Figure 5.7, this figure represents wind based on a monthly reference period for the entire year (Ref. 5.12). Similar data are available for the Eastern Test Range in Reference 5.13.



January

February

Legend.
· 50 Percentile
□ 84.1 Percentile
▽ 97.72 Percentile
○ 99.865 Percentile

March

April

FIGURE 5.7A EMPIRICAL RANGE AND CROSSRANGE WIND COMPONENT ENVELOPES FOR VARIOUS PERCENTILES, EASTERN TEST RANGE (CAPE KENNEDY, FLORIDA), 12 km ALTITUDE JANUARY TO APRIL

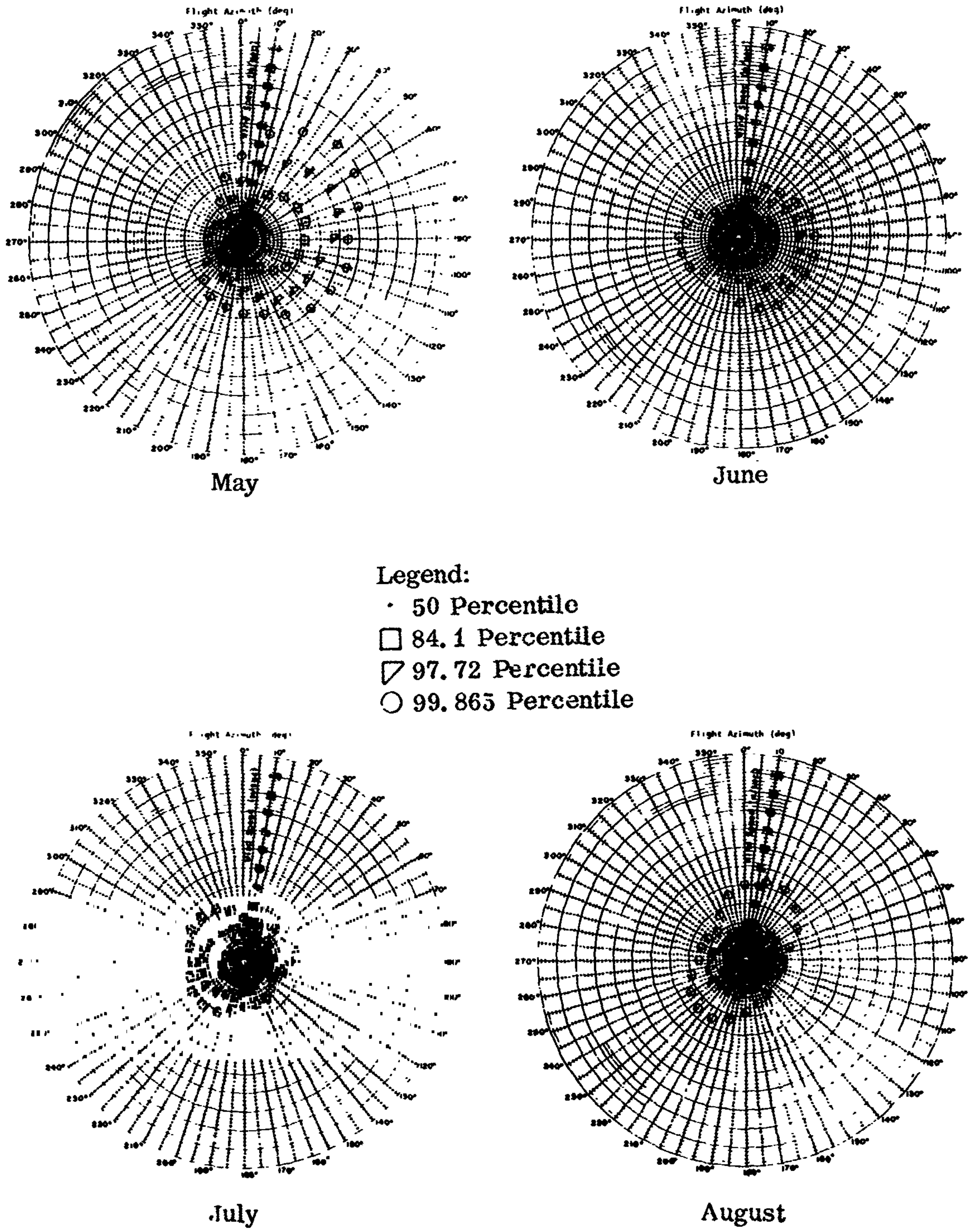
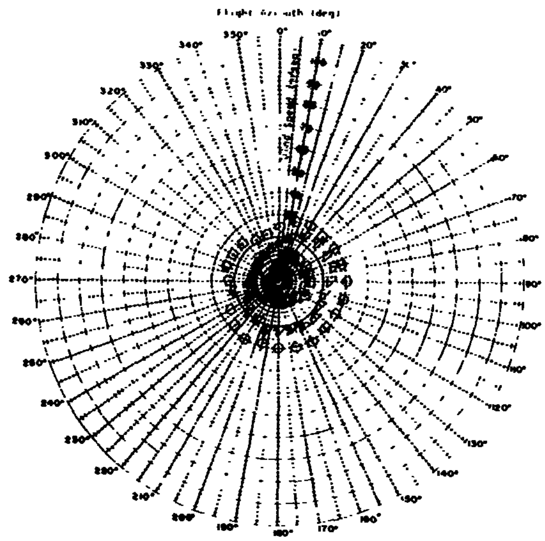
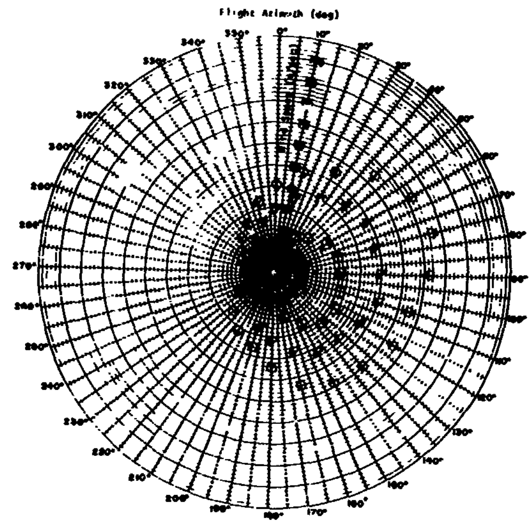


FIGURE 5.7B EMPIRICAL RANGE AND CROSSRANGE WIND COMPONENT ENVELOPES FOR VARIOUS PERCENTILES, EASTERN TEST RANGE (CAPE KENNEDY, FLORIDA), 12 km ALTITUDE MAY TO AUGUST



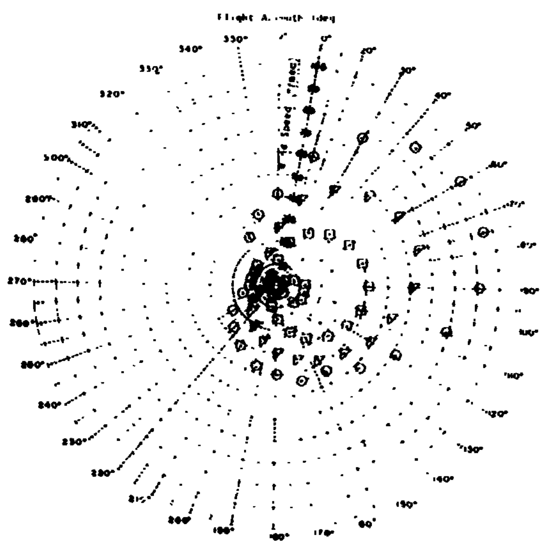
September



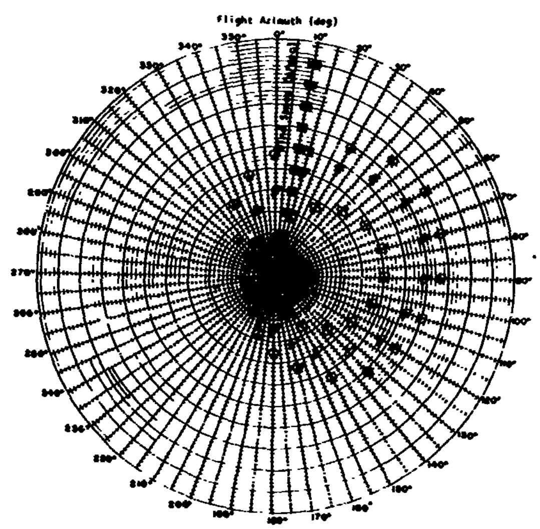
October

Legend:

- · 50 Percentile
- □ 84.1 Percentile
- ▽ 97.72 Percentile
- ○ 99.865 Percentile



November



December

FIGURE 5.7C EMPIRICAL RANGE AND CROSSRANGE WIND COMPONENT ENVELOPES FOR VARIOUS PERCENTILES, EASTERN TEST RANGE (CAPE KENNEDY, FLORIDA), 12 km ALTITUDE SEPTEMBER TO DECEMBER

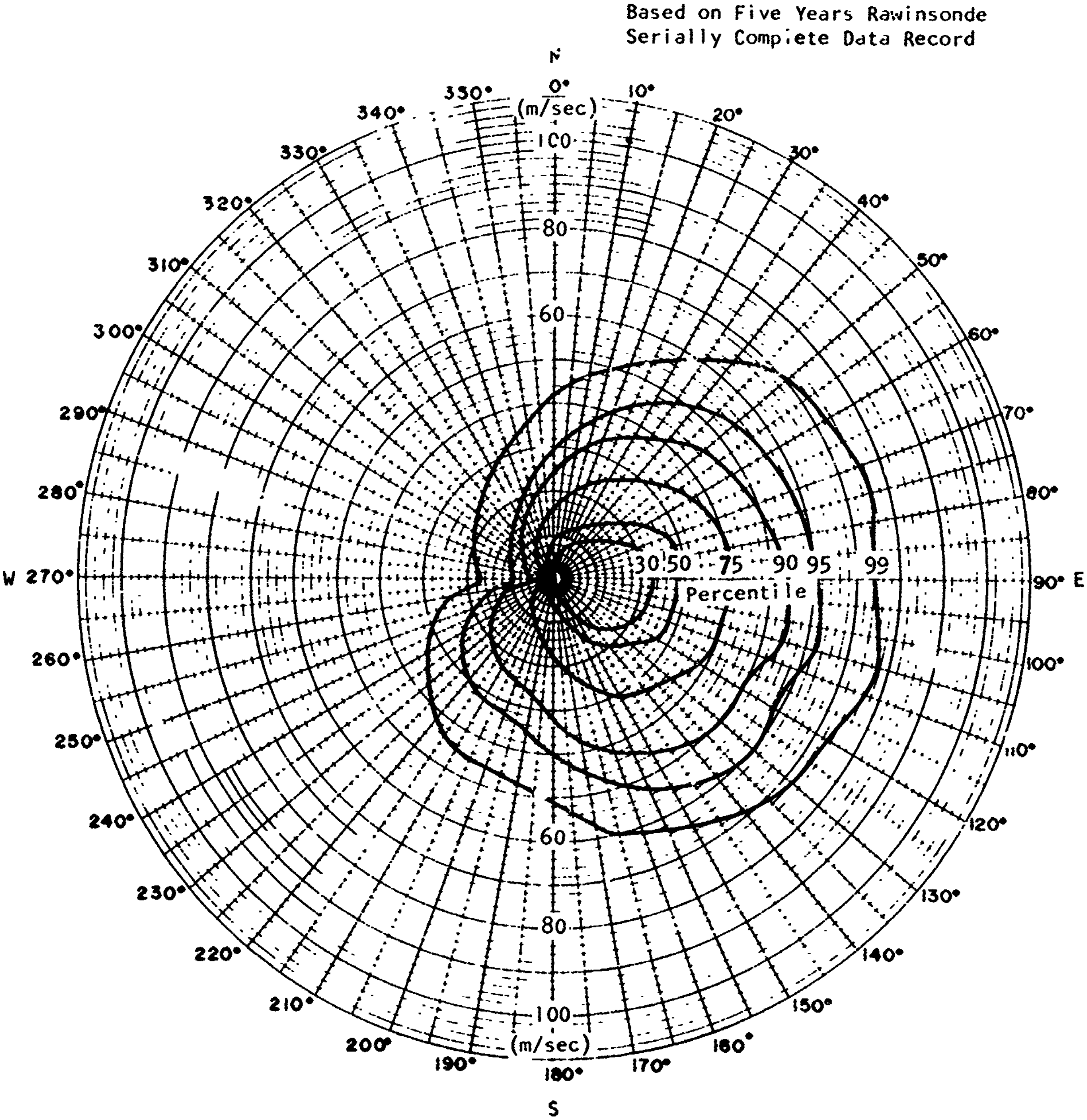


FIGURE 5.8 ENVELOPES OF IDEALIZED MONTHLY WIND COMPONENT (HEAD, TAIL, RIGHT CROSS, AND LEFT CROSS) FREQUENCY DISTRIBUTIONS, FOR 10 TO 13-km ALTITUDE, AS A FUNCTION OF FLIGHT AZIMUTH, WESTERN TEST RANGE (SANTA MONICA, CALIFORNIA). BASED ON WINDIEST MONTHLY REFERENCE PERIOD CONCEPT.

5.2.3.2 Exposure Period Probabilities (10-15 km)

For space vehicles requiring several hours to several days launch preparation, or when launch windows are imposed, it is often desirable to know the probability of exceeding a given wind magnitude during a specified time interval. For example, suppose the launch window is three days and there is a specified wind restriction, then the question of launch probability should be considered. This is expressed in terms of exposure period probabilities.

The eight years serially completed rawinsonde wind profile data for ETR were used to determine monthly exposure period probabilities of maximum winds in the 10-15 km layer. These probabilities are given in Tables 5.9A through 5.9D as a function of wind speed and exposure period. The Tables show the empirical probabilities for each month, in the 10-15 km altitude layer, of getting at least one wind speed equal to or greater than the values shown during k(1 to 10) 12-hour periods. For example, from Table 5.9A, during January there is a 19 percent chance that a wind speed of 70 ms^{-1} or greater will occur during any 3 consecutive 12-hour periods (36 hours); a 1 percent chance that a wind speed of 90 ms^{-1} or greater will occur during any 4 consecutive 12-hour periods (48 hours), etc. These statistics are based on available twice daily wind profile measurements.

In determining the probabilities given in Tables 5.9A through 5.9D, only the maximum wind speed from each profile over the altitude interval 10-15 km inclusive was used. The wind speeds given, in general, extended over only a fraction of the 10-15 km layer. For information on the thickness of the maximum wind layer see Section 5.2.3.4.

5.2.3.3 Probability of Persistence of Winds Above Specified Values

Wind speeds persist over varying intervals of time. The percentage of time that a measured wind speed will persist over varying time periods is considered in this section. This information is useful in determining launch probabilities within specified time periods for wind-limited vehicles from a knowledge of present wind conditions.

Persistence for higher wind speeds (March) for the Eastern Test Range is shown in Figure 5.9A, and for some lower wind speeds (July) in Figure 5.9B. In Figure 5.9A the probability is given that a wind speed will persist over n consecutive 12-hour periods once it has occurred, while Figure 5.9B shows also the probability that a wind speed will exceed a given measured value over n consecutive 12-hour periods. These persistence calculations are based on available twice-daily rawinsonde wind profile measurements from Cape Kennedy, Florida. Similar calculations are being made for the Western Test

January

GRP*	Wind Speed (ms^{-1}) 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	100	110
K 1	100.0	100.0	100.0	100.0	98.0	93.8	87.5	79.0	65.7	50.4	35.1	23.6	15.9	11.1	5.0	3.4	1.5	.2	.2	.0
K 2	100.0	100.0	100.0	100.0	98.8	96.4	91.3	84.5	73.8	59.5	44.2	30.8	20.6	15.5	8.5	5.4	2.5	.4	.4	.0
K 3	100.0	100.0	100.0	100.0	99.4	97.6	94.0	87.3	78.2	65.3	50.8	[illegible]	24.4	19.0	10.9	7.7	3.9	.6	.6	.0
K 4	100.0	100.0	100.0	100.0	99.6	97.8	95.6	89.1	80.8	69.4	55.4	39.7	26.0	22.4	12.9	9.5	4.8	1.0	[illegible]	.0
K 5	100.0	100.0	100.0	100.0	99.6	98.0	96.4	90.7	83.5	72.2	58.9	42.9	31.3	25.2	14.9	11.3	5.8	1.2	1	.0
K 6	100.0	100.0	100.0	100.0	99.6	98.2	97.2	92.1	85.7	74.4	61.5	45.8	34.7	27.8	16.5	12.9	6.9	1.4	1 .	.0
K 7	100.0	100.0	100.0	100.0	99.6	98.2	97.6	93.1	87.3	76.6	63.7	48.4	37.9	[illegible]	19.1	14.5	7.9	1.6	1.4	.0
K 8	100.0	100.0	100.0	100.0	99.6	98.2	97.8	93.8	88.7	78.2	65.7	50.4	40.[illegible]	33.1	19.8	16.1	8.9	1.8	1.6	.0
K 9	100.0	100.0	100.0	100.0	99.6	98.2	98.0	94.4	89.7	79.8	67.5	52.0	42.5	35.3	21.2	17.[illegible]	9.9	2.0	1.8	.0
K 10	100.0	100.0	100.0	100.0	99.6	98.2	98.0	95.0	90.7	80.4	69.2	53.2	44.2	37.3	22.6	18.8	10.7	2.2	2.0	.0

* K is number of 12-hour intervals

February

GRP	Wind Speed (ms^{-1}) 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	100	110
K 1	100.0	100.0	99.8	98.0	91.4	84.3	78.1	68.8	57.5	46.2	36.5	28.1	19.7	11.9	8.6	6.6	4.9	3.8	.0	.0
K 2	100.0	100.0	100.0	99.1	94.9	87.8	82.5	75.2	64.4	53.3	43.1	34.3	24.8	15.3	10.8	9.4	6.9	5.3	.0	.0
K 3	100.0	100.0	100.0	99.6	96.5	90.7	85.6	79.2	69.2	58.6	48.0	38.9	29.2	17.9	12.4	9.7	8.2	6.9	.0	.0
K 4	100.0	100.0	100.0	99.8	97.1	92.7	88.7	83.0	73.2	63.1	52.4	42.3	33.2	20.4	13.9	10.8	9.1	7.7	.0	.0
K 5	100.0	100.0	100.0	100.0	97.6	94.0	90.9	85.2	76.8	67.0	56.2	45.1	36.3	22.3	15.0	11.9	10.0	8.6	.0	.0
K 6	100.0	100.0	100.0	100.0	98.0	95.4	92.7	87.4	79.9	71.0	60.0	47.8	38.7	24.3	16.2	12.8	10.8	9.3	.0	.0
K 7	100.0	100.0	100.0	100.0	98.2	96.2	94.0	89.4	82.7	74.6	63.5	50.2	40.7	26.5	17.3	13.5	11.3	9.5	.0	.0
K 8	100.0	100.0	100.0	100.0	98.5	97.1	94.9	90.5	85.2	77.7	66.8	52.7	42.5	28.8	18.4	14.2	11.7	9.7	.0	.0
K 9	100.0	100.0	100.0	100.0	98.7	97.8	95.8	91.4	86.9	80.1	70.1	54.9	44.0	31.0	19.5	14.8	12.2	10.0	.0	.0
K 10	100.0	100.0	100.0	100.0	98.9	98.5	96.7	92.3	88.3	81.6	73.0	57.1	46.0	33.4	20.8	15.7	12.8	10.2	.0	.0

March

GRP	Wind Speed (ms^{-1}) 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	100	110
K 1	100.0	100.0	100.0	99.8	97.6	94.0	88.5	79.8	70.8	57.5	43.3	31.9	20.2	13.7	8.5	5.0	2.4	1.4	.6	.2
K 2	100.0	100.0	100.0	100.0	99.0	95.8	91.7	85.9	78.8	65.5	53.6	41.9	27.0	19.2	12.3	7.1	3.4	1.3	1.0	.4
K 3	100.0	100.0	100.0	100.0	99.4	97.2	94.2	89.5	84.1	70.8	61.3	49.4	32.7	23.6	15.5	9.1	4.4	2.2	1.4	.6
K 4	100.0	100.0	100.0	100.0	99.6	97.8	95.8	92.1	87.9	74.4	67.1	55.2	37.7	27.4	18.3	10.9	5.2	2.6	1.8	.8
K 5	100.0	100.0	100.0	100.0	100.0	98.2	96.6	94.0	90.1	77.2	71.4	60.3	42.5	31.3	21.4	12.5	6.0	3.0	2.2	1.0
K 6	100.0	100.0	100.0	100.0	100.0	98.8	97.2	95.0	91.5	79.2	74.2	63.9	47.2	34.7	23.8	13.9	6.9	3.4	2.6	1.2
K 7	100.0	100.0	100.0	100.0	100.0	99.4	97.8	96.0	92.5	80.6	76.6	66.7	50.8	37.5	26.0	15.3	7.7	3.8	3.0	1.4
K 8	100.0	100.0	100.0	100.0	100.0	99.6	98.2	96.8	93.5	81.9	78.6	69.4	54.0	40.5	28.2	16.7	8.5	4.2	3.4	1.6
K 9	100.0	100.0	100.0	100.0	100.0	99.8	98.4	97.4	94.6	83.1	79.8	71.2	57.1	43.3	30.2	18.1	9.3	4.6	3.8	1.8
K 10	100.0	100.0	100.0	100.0	100.0	100.0	98.6	98.0	95.4	84.3	81.0	73.0	59.3	45.6	31.9	19.4	9.9	5.0	4.2	2.0

TABLE 5.9A EXPOSURE PERIOD PROBABILITIES (10-15 km), EASTERN TEST RANGE, BASED ON EIGHT YEARS SERIALLY COMPLETED RAWINSONDE DATA JANUARY TO MARCH

April

GRP	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	100	110
	Wind Speed (ms^{-1})																			
K 1	100.0	99.6	95.2	90.4	83.8	76.5	67.5	58.8	47.1	34.8	24.4	17.9	10.2	5.8	2.7	1.3	1.0	.2	.0	.0
K 2	100.0	99.	96.5	92.3	86.9	80.0	72.9	64.6	54.6	41.9	30.2	22.7	14.4	9.0	4.4	2.1	1.9	.4	.0	.0
K 3	100.0	100.0	97.3	94.0	88.8	82.5	76.0	68.5	59.2	47.3	34.8	26.3	17.5	11.3	5.6	2.7	2.5	.6	.0	.0
K 4	100.0	100.0	97.7	95.2	90.8	85.0	79.0	71.9	62.9	52.1	38.8	29.0	19.6	12.9	6.9	3.3	3.1	.8	.0	.0
K 5	100.0	100.0	98.1	95.8	92.3	87.3	81.3	74.6	66.3	55.2	42.1	31.5	21.3	14.6	7.5	3.8	3.5	1.0	.0	.0
K 6	100.0	100.0	98.5	96.3	93.8	88.5	83.1	76.9	66.8	57.9	44.8	33.8	22.7	16.3	8.1	4.2	4.0	1.3	.0	.0
K 7	100.0	100.0	99.0	96.7	94.8	89.8	85.0	79.6	71.0	60.4	47.1	35.2	24.2	17.9	8.8	4.6	4.4	1.5	.0	.0
K 8	100.0	100.0	99.4	97.1	95.4	90.8	86.9	82.3	73.5	63.1	49.6	36.9	25.1	19.4	9.4	5.0	4.8	1.7	.0	.0
K 9	100.0	100.0	99.8	97.3	96.0	91.7	88.3	84.4	75.8	65.6	[illegible]	38.8	26.5	20.8	10.0	5.4	5.2	1.9	.0	.0
K 10	100.0	100.0	100.0	97.5	96.5	92.5	89.6	86.3	77.7	67.9	55.0	40.6	27.5	22.3	10.6	5.8	5.6	2.1	.0	.0

May

GRP	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	100	110
	Wind Speed (ms^{-1})																			
K 1	100.0	97.4	86.5	73.4	52.0	36.1	27.4	19.2	10.7	6.9	3.2	1.2	.6	.4	.2	.0	.0	.0	.0	.0
K 2	100.0	99.4	90.5	80.6	61.3	43.3	33.5	24.4	15.1	9.1	5.0	2.2	1.2	.8	.4	.0	.0	.0	.0	.0
K 3	100.0	99.4	92.5	85.1	67.7	48.4	38.5	28.4	19.0	11.3	6.5	3.2	1.8	1.2	.6	.0	.0	.0	.0	.0
K 4	100.0	99.8	94.0	87.9	71.6	52.6	42.5	32.5	22.0	13.3	7.9	4.0	2.2	1.6	.8	.0	.0	.0	.0	.0
K 5	100.0	100.0	95.2	89.3	74.6	56.5	46.4	35.7	25.0	15.3	9.1	4.6	2.6	2.0	1.0	.0	.0	.0	.0	.0
K 6	100.0	100.0	96.4	90.7	77.0	59.9	49.8	38.7	27.5	16.9	10.3	5.2	3.0	2.4	[illegible]	.0	.0	.0	.0	.0
K 7	100.0	100.0	97.0	91.9	79.4	62.7	52.4	41.1	29.4	17.9	11.1	5.8	3.4	2.8	1.4	.0	.0	.0	.0	.0
K 8	100.0	100.0	97.4	93.3	82.1	64.9	54.4	43.8	30.8	18.5	11.7	6.3	3.8	3.2	1.6	.0	.0	.0	.0	.0
K 9	100.0	100.0	97.8	94.4	84.3	66.9	56.3	45.4	32.3	19.2	12.1	6.5	[illegible]	3.6	1.8	.0	.0	.0	.0	.0
K 10	100.0	100.0	98.2	95.4	85.7	69.2	58.1	47.2	33.7	19.8	12.5	6.7	4.6	4.0	2.0	.0	.0	.0	.0	.0

June

GRP	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	100	110
	Wind Speed (ms^{-1})																			
K 1	99.4	87.5	59.4	37.3	21.9	13.3	7.3	3.5	1.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 2	100.0	94.2	71.3	47.1	29.4	17.3	11.0	5.7	2.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 3	100.0	97.9	77.3	53.5	34.6	20.8	14.0	7.7	2.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 4	100.0	99.4	82.1	59.8	39.4	24.2	16.0	9.0	3.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 5	100.0	99.8	85.4	64.6	43.3	27.1	18.1	10.2	4.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 6	100.0	100.0	88.3	69.0	46.9	29.6	20.0	11.5	4.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 7	100.0	100.0	90.4	72.3	50.2	32.1	21.7	12.7	5.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 8	100.0	100.0	92.3	75.2	52.9	34.2	23.1	13.8	5.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 9	100.0	100.0	94.0	77.7	55.2	36.3	24.4	14.8	6.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 10	100.0	100.0	95.6	79.8	57.3	38.1	25.6	15.6	7.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

TABLE 5.9B EXPOSURE PERIOD PROBABILITIES (10-15 km), EASTERN TEST RANGE
BASED ON EIGHT YEARS SERIALLY COMPLETED RAWINSONDE DATA
APRIL TO JUNE

July

GRP	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	100	110
							Wind Speed (ms^{-1})													
K 1	99.2	83.5	44.8	18.5	6.9	2.8	.6	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 2	100.0	92.1	59.1	26.4	10.3	4.0	1.0	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 3	100.0	96.2	66.5	32.3	13.7	5.0	1.4	.6	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 4	100.0	98.0	72.8	37.7	16.9	5.8	1.8	.8	.0	.0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 5	100.0	98.8	78.2	42.5	20.0	6.7	2.2	1.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 6	100.0	99.4	82.5	46.8	22.6	7.5	2.6	1.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 7	100.0	99.8	85.9	51.0	25.4	8.3	3.0	1.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 8	100.0	100.0	88.5	54.8	28.2	9.1	3.4	1.6	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 9	100.0	100.0	90.3	57.9	30.8	10.3	4.0	1.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 10	100.0	100.0	92.1	60.9	33.3	11.5	4.6	2.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

August

GRP	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	100	110
									Wind Speed (ms^{-1})											
K 1	99.4	75.4	37.1	13.5	4.2	1.2	.6	.2	.2	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 2	100.0	86.1	49.8	19.8	6.5	2.2	1.0	.4	.4	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 3	100.0	92.7	58.9	25.0	8.5	3.0	1.4	.6	.6	.6	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 4	100.0	95.2	66.7	30.0	10.3	3.8	1.8	.8	.8	.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 5	100.0	97.0	73.2	35.1	12.1	4.6	2.2	1.0	1.0	1.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 6	100.0	98.0	77.8	39.1	13.9	5.4	2.6	1.2	1.2	1.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 7	100.0	98.8	81.7	42.7	15.5	6.3	3.0	1.4	1.4	1.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 8	100.0	99.2	84.7	46.2	17.1	7.1	3.4	1.6	1.6	1.6	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 9	100.0	99.4	87.1	49.4	18.3	7.5	3.6	1.8	1.8	1.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 10	100.0	99.6	89.3	52.4	19.6	7.9	3.8	2.0	2.0	2.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

September

GRP	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	100	110
								Wind Speed (ms^{-1})												
K 1	97.9	83.5	57.5	33.3	15.4	5.4	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 2	99.6	91.9	66.5	42.5	20.8	9.0	.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 3	100.0	95.4	72.9	49.8	25.8	12.3	1.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 4	100.0	97.3	77.9	56.7	30.1	15.4	1.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 5	100.0	98.5	81.9	62.9	34.6	18.1	2.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 6	100.0	99.6	85.4	68.1	38.5	20.6	2.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 7	100.0	100.0	88.1	72.3	42.7	23.3	3.1	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 8	100.0	100.0	91.0	76.0	46.9	25.8	3.9	.4	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 9	100.0	100.0	93.3	79.8	51.0	28.3	4.4	.6	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
K 10	100.0	100.0	95.2	82.9	55.0	30.8	5.0	.8	.6	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

TABLE 5.9C EXPOSURE PERIOD PROBABILITIES (10-15 km), EASTERN TEST RANGE, BASED ON EIGHT YEARS SERIALLY COMPLETED RAWINSONDE DATA JULY TO SEPTEMBER

October

GRP	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	100	110
								Wind Speed (ms^{-1})												
K 1	99.4	96.0	86.3	72.4	55.2	39.9	28.0	18.1	10.3	6.9	3.4	1.4	.8	.6	.4	.2	.0	.0	.0	.0
K 2	100.0	98.8	91.3	80.4	63.7	48.8	35.7	24.4	14.3	9.7	5.2	2.2	1.4	1.0	.8	.4	.0	.0	.0	.0
K 3	100.0	99.6	93.5	84.9	69.4	55.8	41.9	29.6	18.1	12.3	6.7	2.8	1.8	1.2	1.2	.6	.0	.0	.0	.0
K 4	100.0	100.0	95.6	88.7	73.6	61.3	47.2	34.3	21.4	14.7	7.9	3.4	2.2	1.4	1.4	.8	.0	.0	.0	.0
K 5	100.0	100.0	96.8	91.5	77.4	65.7	51.4	38.1	25.0	17.3	9.3	4.0	2.6	1.6	1.6	1.0	.0	.0	.0	.0
K 6	100.0	100.0	98.0	94.0	80.8	69.6	55.4	41.9	28.6	20.2	10.7	4.6	3.0	1.8	1.8	1.2	.0	.0	.0	.0
K 7	100.0	100.0	99.2	96.0	84.1	73.0	59.3	45.6	32.1	22.8	12.1	5.4	3.4	2.0	2.0	1.4	.0	.0	.0	.0
K 8	100.0	100.0	99.8	97.8	86.5	76.4	62.9	48.8	35.1	25.2	13.5	6.3	4.0	2.2	2.2	1.6	.0	.0	.0	.0
K 9	100.0	100.0	100.0	99.0	88.7	79.2	66.3	51.6	[illegible]	27.6	14.9	7.1	4.6	2.4	2.4	1.8	.0	.0	.0	.0
K 10	100.0	100.0	100.0	99.6	90.5	82.1	69.6	54.4	40.5	29.8	16.3	7.7	5.2	2.6	2.6	2.0	.0	.0	.0	.0

November

GRP	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	100	110
								Wind Speed (ms^{-1})												
K 1	100.0	99.6	96.9	90.0	84.0	70.4	54.0	37.3	22.9	12.7	7.7	6.0	3.3	2.3	1.5	1.0	.4	.4	.0	.0
K 2	100.0	100.0	98.8	93.5	88.3	79.0	64.8	47.7	30.0	17.9	10.4	8.3	5.4	3.3	2.1	1.5	.6	.6	.0	.0
K 3	100.0	100.0	99.8	95.4	91.0	84.2	73.1	55.8	36.7	22.3	12.7	10.6	6.9	4.4	2.7	1.7	.8	.8	.0	.0
K 4	100.0	100.0	100.0	96.3	93.1	87.9	79.6	63.3	42.9	26.7	15.0	12.7	8.1	5.4	3.3	1.9	1.0	1.0	.0	.0
K 5	100.0	100.0	100.0	96.7	94.5	91.3	83.8	69.4	48.1	31.0	17.3	14.4	9.2	6.3	4.0	2.1	1.3	1.3	.0	.0
K 6	100.0	100.0	100.0	97.1	95.6	93.5	87.3	73.5	52.9	35.0	19.8	16.3	10.4	7.1	4.6	2.3	1.5	1.5	.0	.0
K 7	100.0	100.0	100.0	97.5	96.7	94.6	89.8	77.1	57.3	38.5	22.1	18.1	11.7	7.9	5.2	2.5	1.7	1.7	.0	.0
K 8	100.0	100.0	100.0	97.7	97.3	95.6	91.5	80.0	61.3	42.1	24.6	20.2	12.7	8.8	5.6	2.7	1.9	1.9	.0	.0
K 9	100.0	100.0	100.0	97.9	97.5	96.5	93.1	82.9	64.8	45.6	27.1	22.3	14.0	9.6	6.0	2.9	2.1	2.1	.0	.0
K 10	100.0	100.0	100.0	98.1	97.7	97.1	94.4	85.6	68.1	48.8	29.6	24.4	15.4	10.6	6.7	3.3	2.5	2.5	.0	.0

December

GRP	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	100	110
								Wind Speed (ms^{-1})												
K 1	100.0	100.0	99.8	97.8	88.1	79.4	69.8	59.7	46.2	35.7	24.6	16.5	10.1	5.4	3.2	.6	.2	.2	.0	.0
K 2	100.0	100.0	100.0	98.8	92.5	82.9	75.2	67.5	53.8	43.5	32.7	23.2	14.7	8.1	5.0	1.4	.4	.4	.0	.0
K 3	100.0	100.0	100.0	99.2	96.2	85.7	78.6	73.0	59.1	50.4	39.5	29.4	19.4	10.7	6.9	2.0	.6	.6	.0	.0
K 4	100.0	100.0	100.0	99.4	97.6	87.7	81.0	76.0	63.3	56.[illegible]	45.6	34.7	23.6	13.3	8.5	2.6	.8	.8	.0	.0
K 5	100.0	100.0	100.0	99.6	98.6	89.5	83.1	78.6	66.5	60.9	51.4	39.1	27.2	15.9	10.1	3.2	1.0	1.0	.0	.0
K 6	100.0	100.0	100.0	99.8	99.0	91.1	84.9	80.6	69.2	64.1	55.8	43.1	30.0	18.3	11.7	3.8	1.2	1.2	.0	.0
K 7	100.0	100.0	100.0	100.0	99.2	91.9	86.5	82.3	71.8	66.7	59.5	46.6	32.9	20.6	13.3	4.4	1.4	1.4	.0	.0
K 8	100.0	100.0	100.0	100.0	99.4	92.7	87.9	83.5	73.6	69.2	62.5	49.8	35.7	22.8	14.9	5.0	1.6	1.6	.0	.0
K 9	100.0	100.0	100.0	100.0	99.6	93.1	88.9	84.7	75.4	71.0	64.9	52.6	38.3	25.0	16.5	5.6	1.8	1.8	.0	.0
K 10	100.0	100.0	100.0	100.0	99.8	93.5	89.7	85.9	77.2	72.8	66.9	54.8	40.7	27.2	17.9	6.0	1.8	1.8	.0	.0

TABLE 5.9D EXPOSURE PERIOD PROBABILITIES (10-15 km), EASTERN TEST RANGE
BASED ON EIGHT YEARS SERIALLY COMPLETED RAWINSONDE DATA
OCTOBER TO DECEMBER

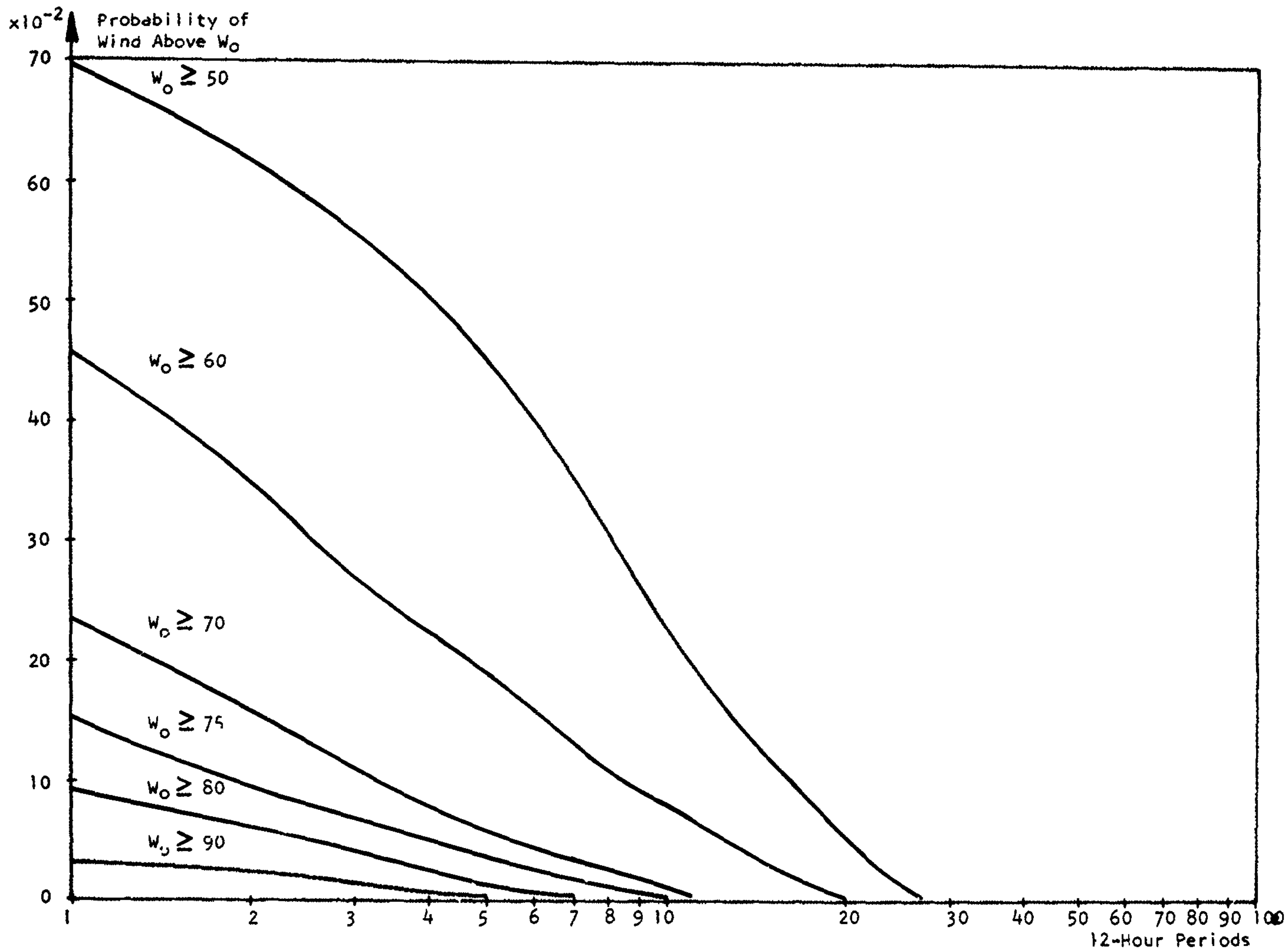


FIGURE 5.9A PROBABILITY OF MAXIMUM SCALAR WIND IN 10-15 km LAYER EXISTING ABOVE SPECIFIED VALUES, W_o (m/sec) FOR n 12-HOUR PERIODS
EASTERN TEST RANGE, FLORIDA
March

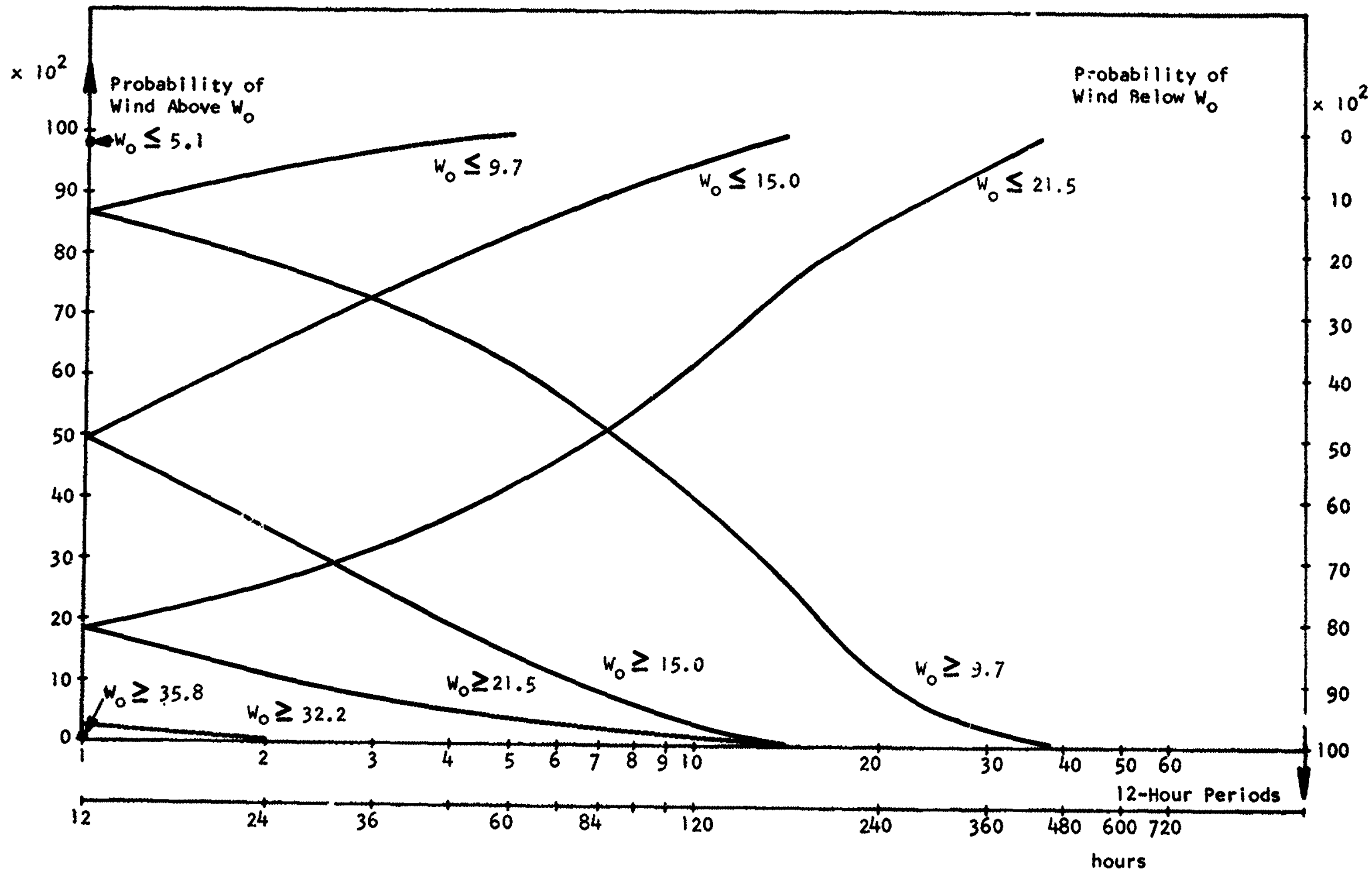


FIGURE 5.9B PROBABILITY OF MAXIMUM SCALAR WIND IN 10-15 km LAYER EXISTING ABOVE AND BELOW SPECIFIED VALUES, W_o (m/sec), FOR n 12-HOUR PERIODS
CAPE KENNEDY, FLORIDA
July

Range based on the available four times daily wind profile measurements from Santa Monica, California.

The probabilities (percentages) for one-12 hour period shown in Figures 5.9A and 5.9B should be the same as those shown in Tables 5.9A - 5.9D when the same data sample is used. Different data samples were used in the two cases. Tables 5.9A - 5.9D are based on a longer period of record and, therefore, should be considered as correct. Figures 5.9A and 5.9B are presented here to illustrate the order of magnitude of the persistence which may be expected. An improved analysis will be forthcoming.

5.2.3.4 Maximum Thickness of Strong Wind Layers

Wind speeds generally increase with altitude and reach a maximum between approximately 10-14 km at middle latitudes. Frequently, a core of maximum winds, the jet stream, is present over mid-latitudes at these altitudes. The vertical extent of this core of maximum winds is important in some vehicle design studies.

Table 5.10A shows the maximum vertical thickness of layers with wind speeds of 50, 75 and 97 m sec^{-1} for ETR, and Table 5.10B for WTR. Maximum thickness of the layer decreases as the wind speed within the layer increases. Stated differently, the sharpness of the peak on a wind profile increases as the peak speed increases.

TABLE 5.10A MAXIMUM THICKNESS OF STRONG WIND LAYERS (6 YEARS RECORD) AT EASTERN TEST RANGE

Quasi-Steady State Wind Speed (±5 m sec^{-1})	Maximum Thickness (km)	Altitude Range (km)
50	5	8.5 to 16.5
75	3	10.5 to 15.5
97	2	10.0 to 14.0

TABLE 5.10B MAXIMUM THICKNESS OF STRONG WIND LAYERS (5 YEARS RECORD) AT WESTERN TEST RANGE

Quasi-Steady-State Wind Speed (±5 m sec^{-1})	Maximum Thickness (km)	Altitude Range (km)
50	5	8.0 to 16
75	3	9.5 to 14
97	-	---

5.2.4 Wind Speed Profiles.

Inflight wind speed profiles are used in vehicle design studies for flight through the atmosphere. The design inflight wind speeds may or may not be the same percentile as the surface wind speed. This depends upon the desired launch capability since the two design wind conditions are essentially independent statistical events.

Inflight wind information is basically of three types: (1) Sample of measured profiles, (2) statistical distributions, and (3) discrete or synthetic profiles. A detailed discussion of these three types of presentations may be found in reference 5.14. Each of these wind input types has certain limitations and the utility in design studies depends upon a number of considerations. Some of these are a. accuracy of basic measurements, b. tolerable complexity of input, c. economy and practicality for design use, d. representation of significant features of the wind profile, e. statistical assumption versus physical representativeness, f. ability to ensure control system and structural integrity, and g. flexibility in design trade-off studies.

The oldest method of presentation of inflight design wind data involves the synthetic-type of wind profile. For this method, various features of the wind profile; i.e., wind speed, shear, gust, maximum wind layer thickness, etc., are described and design values established. In this document, synthetic wind profile-type data are presented because this method of presentation appears to provide a reasonable approach for most design studies when properly employed. In addition, the concept of synthetic profiles is generally understood and employed by most aerospace design organizations.

The desirability of having a common set of design data criteria guidelines is evident. Descriptions of wind inputs are generally available upon request for the various other design approaches such as given in References 5.15 and 5.16 as may be approved by the cognizant design organization. The present report would be too voluminous if data for all methods were included.

The source of the quasi-steady-state wind information for the data up to 30 km altitude is the upper air observations made by the standard AN/GMD 1A atmospheric sounding system (see Section 5.2.2.1). The data for Cape Kennedy, Florida (Eastern Test Range) and Santa Monica, California (Western Test Range) were serially completed (missing data inserted by interpolation, extrapolation, or use of data from nearby stations) by professional meteorologists. An analysis was performed to provide frequency distributions of quasi-steady-state wind speeds and wind shears for each month as well as the annual period. References

5.17, 5.18, 5.19, and 5.20 contain additional data on the statistical distribution of winds for Cape Kennedy, Florida (Eastern Test Range), Wallops Test Range, Virginia, and El Paso, Texas (White Sands Missile Range, New Mexico), respectively. Additional data tabulations are being published as Range Reference Atmospheres by the Meteorological Working Group of the Inter-Range Instrumentation Group (IRIG). Contact the IRIG Secretariat, Range Commanders Conference, White Sands Missile Range, New Mexico, for further information on availability of these documents (Ref. 5.21). Information on interlevel correlations of wind is presented in NASA TN D-561 (Ref. 5.22).

5.2.4.1 Inflight Wind Speed Profile Envelopes (Idealized) to 80 km Altitude.

Idealized quasi-steady-state scalar wind speed profile envelopes are presented herein to altitudes of 80 km. These winds are not expected to be exceeded by the given percentage of time* based on the windiest monthly reference period. The wind data represent horizontal wind flow with reference to the surface of the earth. Vertical wind flow is negligible except perhaps for elastic body considerations of gust (turbulence) characteristics. The horizontal wind speeds are normally applied without regard to flight directions to establish initial vehicle design requirements. Specific percentile wind speed envelopes for design should be specified in the appropriate organizational space vehicle design criteria documentation. The data in the subsequent paragraphs provide for construction of idealized wind speed profile envelopes using linear segments to connect the given data points. The statistical data employed to establish the data points below 30 km altitude consisted of records of at least five years of twice-daily wind profile observations.

Generally, the larger space vehicles for use in comprehensive space research are designed for scalar wind speeds without regard to specific wind directions. However, in special situations, when a vehicle is restricted to a given launch site and to rather narrow flight azimuths (within approximately 20 degrees), for a specific configuration and mission, winds based on components (head, tail, left cross or right cross) may be used. For a given percentile, the magnitudes of component winds are less than those of the scalar winds. They should not be employed in design studies unless specifically authorized by the cognizant design organization. Directional wind component frequency envelopes are presented in Section 5.2.5 for the Eastern Test Range and the Western Test Range. The nondirectional wind speed profile envelopes for the various locations are given in Tables 5.11 - 5.14 and Figures 5.10 - 5.13.

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* Time as used in this expression is related to the observational interval of the data sample.

TABLE 5.11 SCALAR WIND SPEED PROFILE ENVELOPES (QUASI-STEADY-STATE) FOR EASTERN TEST RANGE

Geometric Altitude (km)	Percentile				
	50	75	90	95	99
1	10*	14	18	21	27.5
10	47	57	68	75	97
14	47	57	68	75	97
20	16	18	22	25	40
23	16	18	22	25	40
50	58	73	91	102	120
80	58	73	91	102	120

TABLE 5.12 SCALAR WIND SPEED PROFILE ENVELOPES (QUASI-STEADY-STATE) FOR WESTERN TEST RANGE

Geometric Altitude (km)	Percentile				
		75	90	95	99
1	13.5*	16	19.5	22.5	28
9					80
10		46	60	68	
11	34				
13	34	46	60	68	80
19	10	13	17	21	27
23	10	13	17	21	27
50	60	77	97	110	125
80	60	77	97	110	125

* Wind speed (ms^{-1})

TABLE 5.13 SCALAR WIND SPEED PROFILE ENVELOPES (QUASI-STEADY-STATE) FOR WALLOPS TEST RANGE

Geometric Altitude (km)	Percentile 95	Percentile 99
1	24.5*	30
9.5	75	88
10.5	75	88
20	27	33
23	27	33
50	120	140
80	120	140

TABLE 5.14 SCALAR WIND SPEED PROFILE ENVELOPES (QUASI-STEADY-STATE) FOR WHITE SANDS MISSILE RANGE

Geometric Altitude (km)	Percentile 95	Percentile 99
2.5	27.5*	34.5
11	70	86
13	70	86
19	25	31
23	25	31
50	110	125
80	110	125

* Wind speed (ms^{-1})

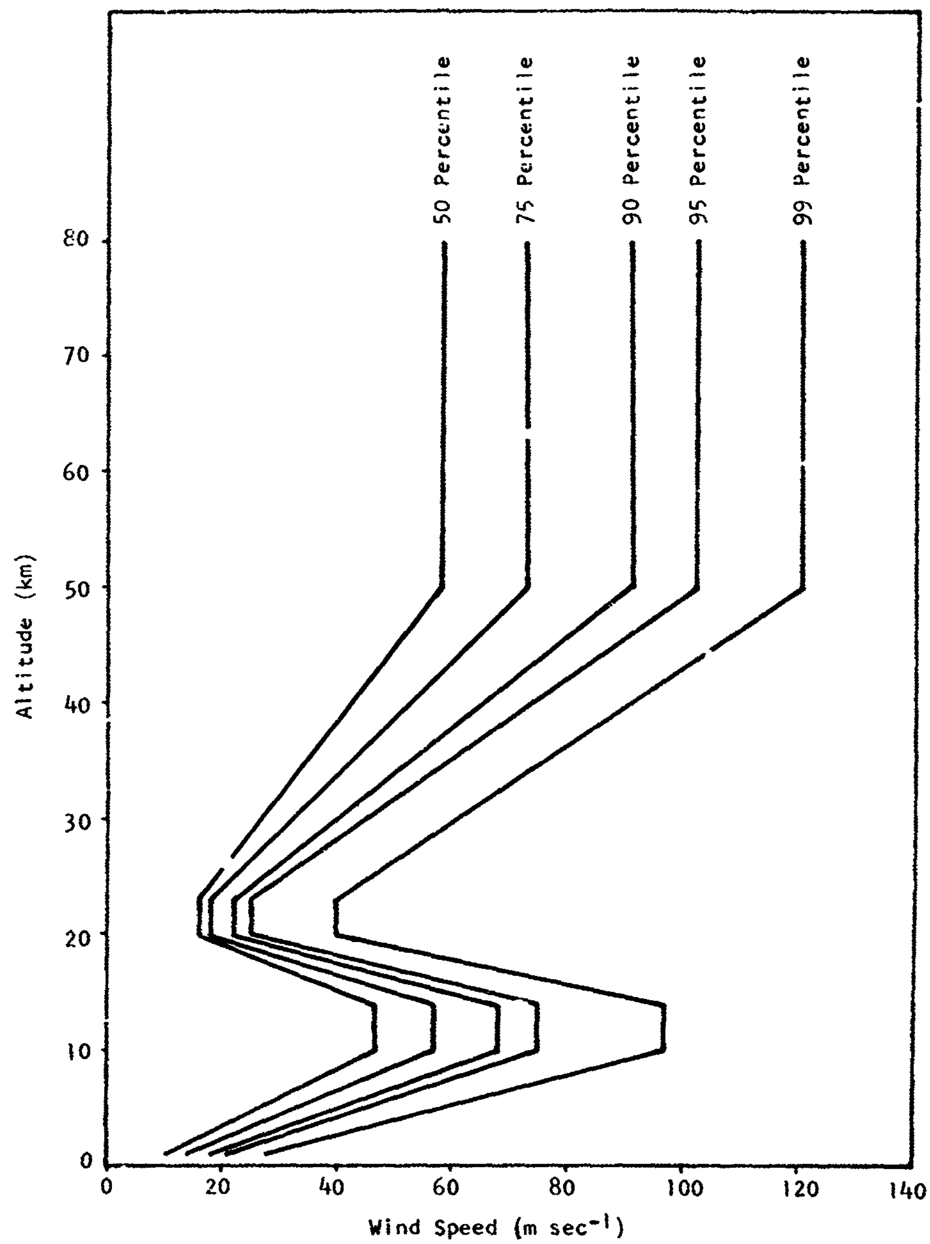


FIGURE 5.10 SCALAR WIND SPEED PROFILE ENVELOPES (QUASI-STEADY-STATE) FOR EASTERN TEST RANGE (PLOTTED FROM TABLE 5.1')

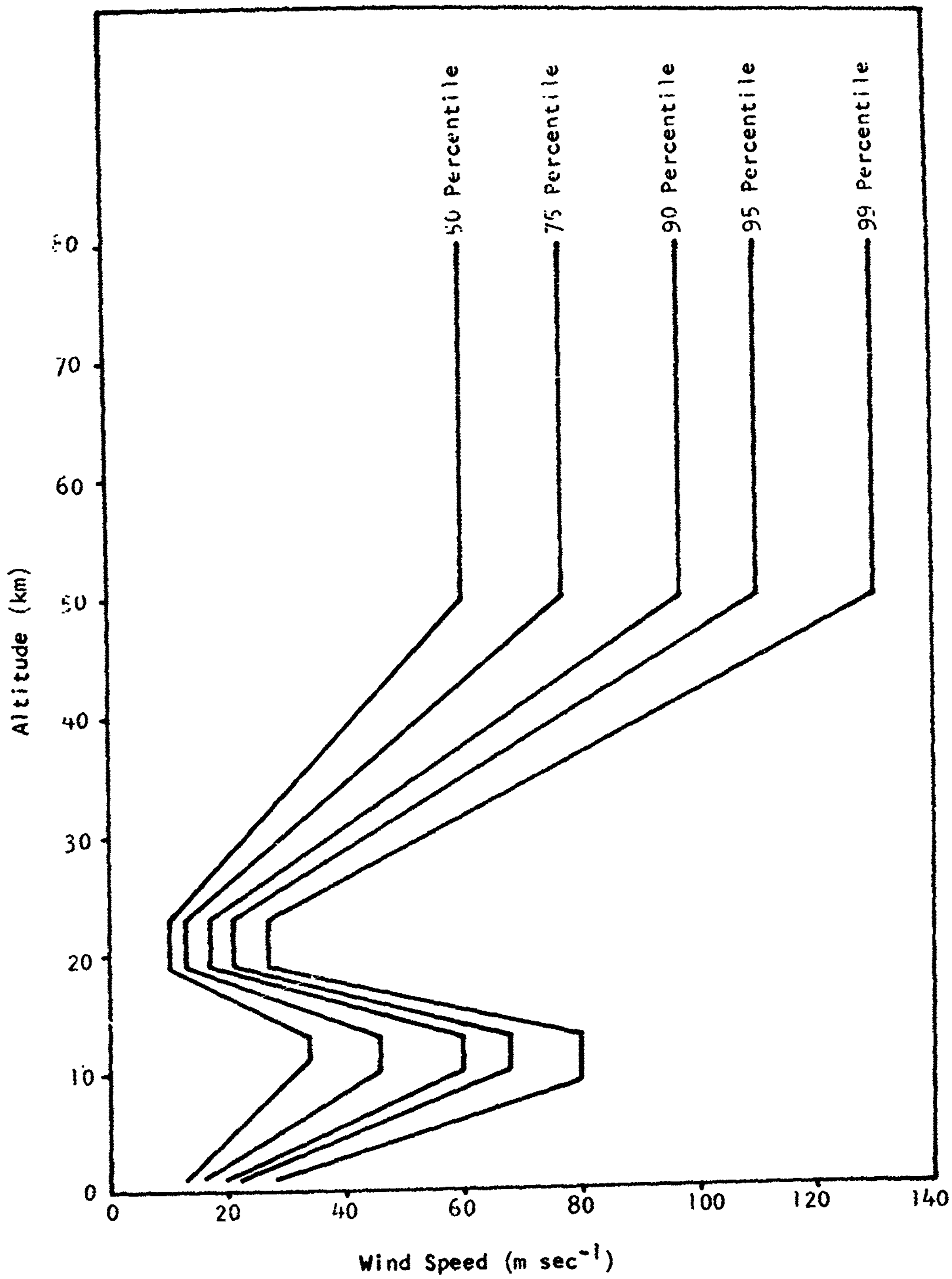


FIGURE 5.11 SCALAR WIND SPEED PROFILE ENVELOPES (QUASI-STEADY-STATE) FOR WESTERN TEST RANGE (PLOTTED FROM TABLE 5.12)

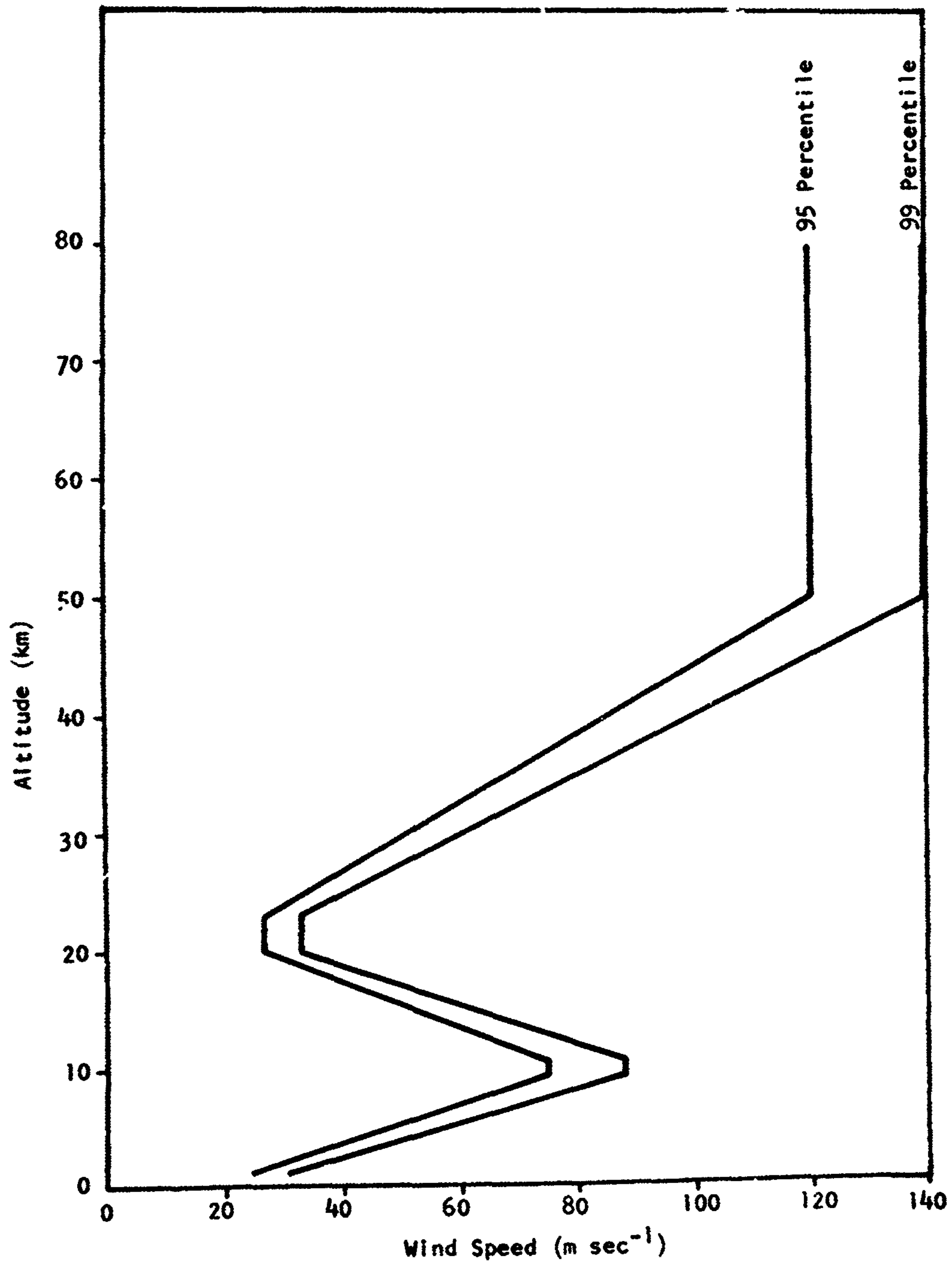


FIGURE 5.12 SCALAR WIND SPEED PROFILE ENVELOPES (QUASI-STEADY-STATE) FOR WALLOPS TEST RANGE (PLOTTED FROM TABLE 5.13)

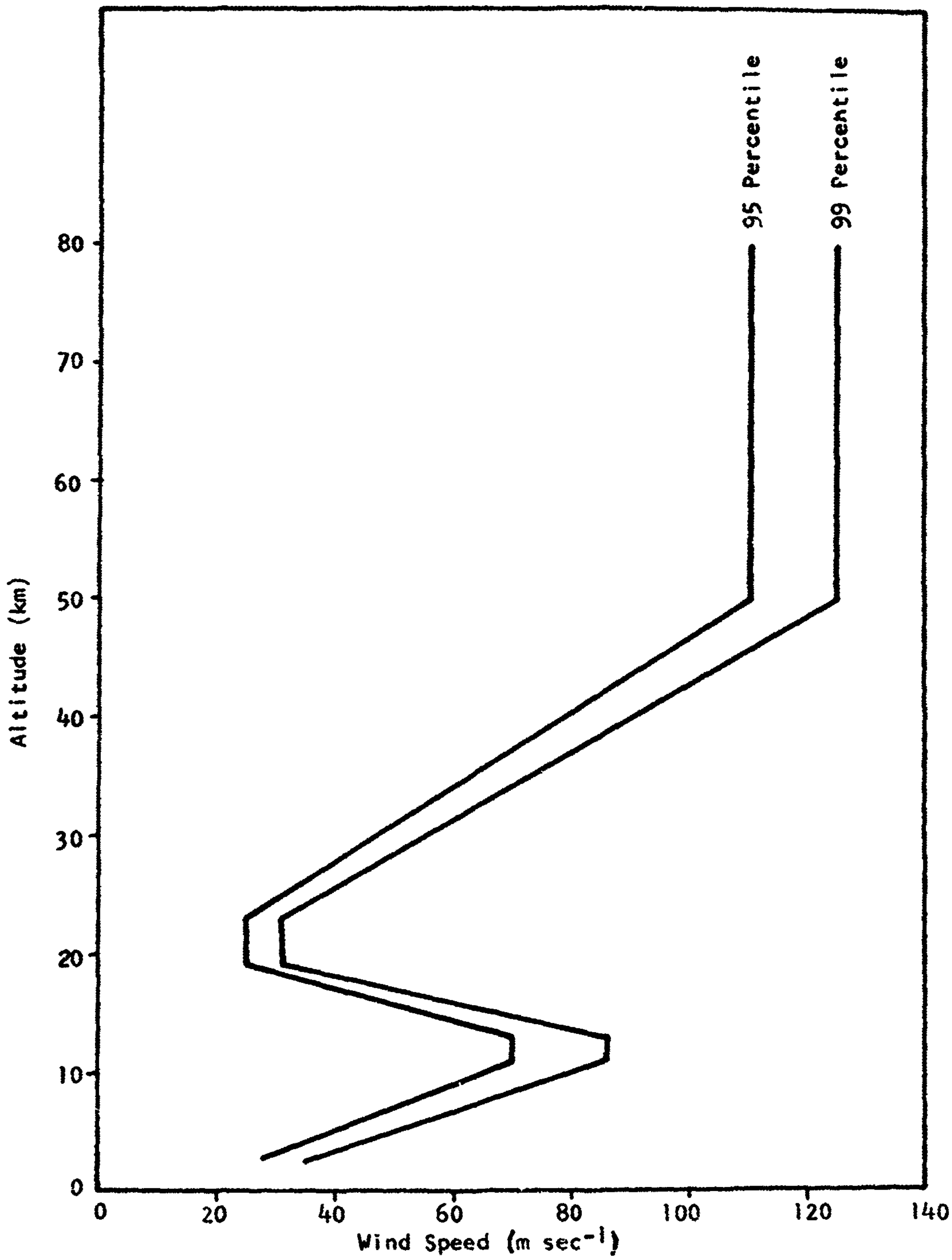


FIGURE 5.13 SCALAR WIND SPEED PROFILE ENVELOPES (QUASI-STEADY-STATE) FOR WHITE SANDS MISSILE RANGE (PLOTTED FROM TABLE 5.14)

5.2.5 Component Wind Speed Profiles for Azimuths of 75, 90 and 105 Degrees at Cape Kennedy, Eastern Test Range.

Questions frequently arise regarding the probability that a given wind speed will occur in the pitch and yaw planes with a given launch azimuth. Most of these questions can be answered satisfactorily from component wind profiles for limited azimuths at the Eastern Test Range.

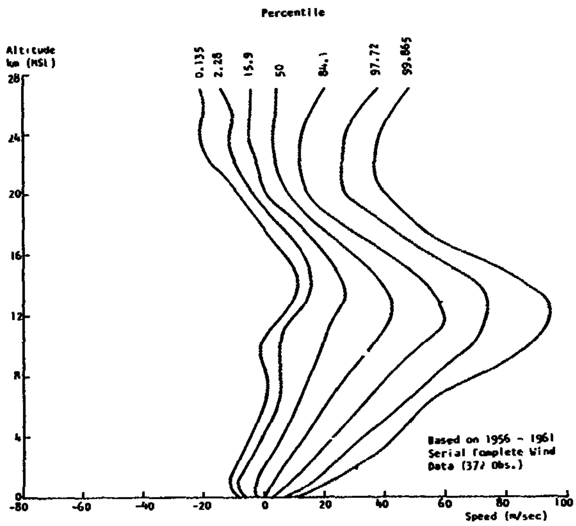
Monthly and annual pitch (range) and yaw (cross range) plane wind profiles for the ETR are given in Figures 5.14A through C, 5.15A through C, 5.16A through C, 5.17A through C, 5.18A through C and 5.19A through C for several percentiles and for flight azimuths of 75, 90, and 105 degrees clockwise from north, respectively. These profiles are envelopes of wind speed for each of the probability levels. They show the probability of wind speeds at each altitude independent of every other altitude. This does not mean there is no correlation between speeds from one altitude to the next, nor that the entire profile occurs at a given time.

Positive pitch plane winds are tail winds (blowing toward the firing azimuth); negative winds are head winds (blowing from the flight azimuth). Positive yaw plane winds are right cross winds (blowing from right to left across the flight path); negative winds are left cross winds (blowing from left to right across the flight path).

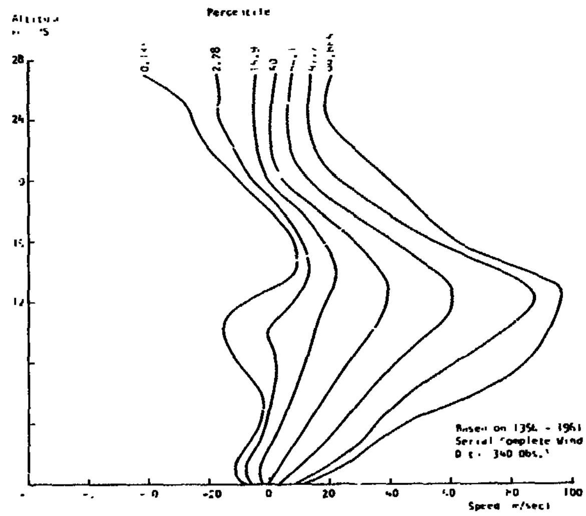
Component wind speed envelopes for other flight azimuths are available upon request to the Aerospace Environment Division.

5.2.6 Wind Speed Profiles for Biasing Tilt Programs

The primary purpose for wind biasing tilt programs is to gain launch capability. In principle, the maximum launch capability can be realized when the biased wind profile is chosen such that the probability of getting a wind between the pitch and yaw plane wind restrictions is a maximum. When the probability density function for winds is nearly symmetrical, as is generally the case when the flight azimuth does not differ greatly from 90 degrees, the median wind profile is adequate for biasing purposes. Monthly median (50 percentile) wind profiles for each month and annual are given in Figures 5.14A through D, 5.15A through D, 5.16A through D, 5.17A through D, 5.18A through D, and 5.19A through D.



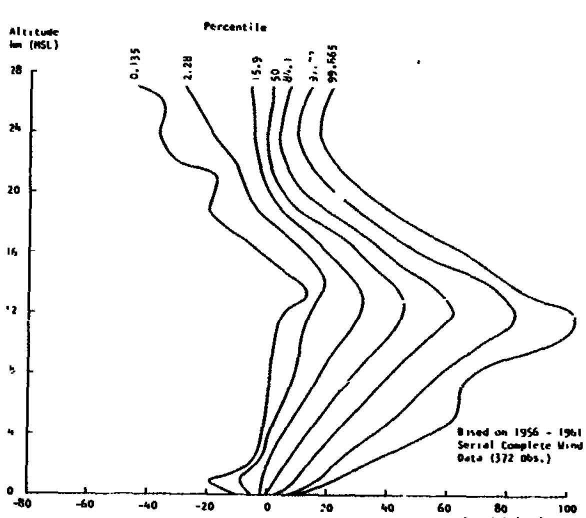
January



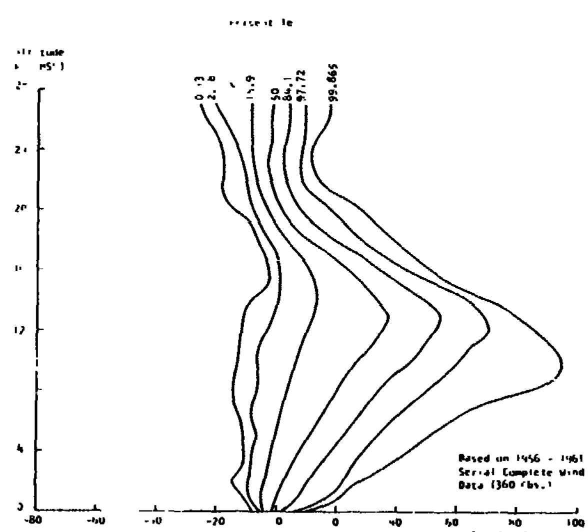
February

Legend:

1. For 75° Flight Azimuth
   Positive Values Tailwind
   Negative Values Headwind
2. For 255° Flight Azimuth
   Positive Values Headwind
   Negative Values Tailwind

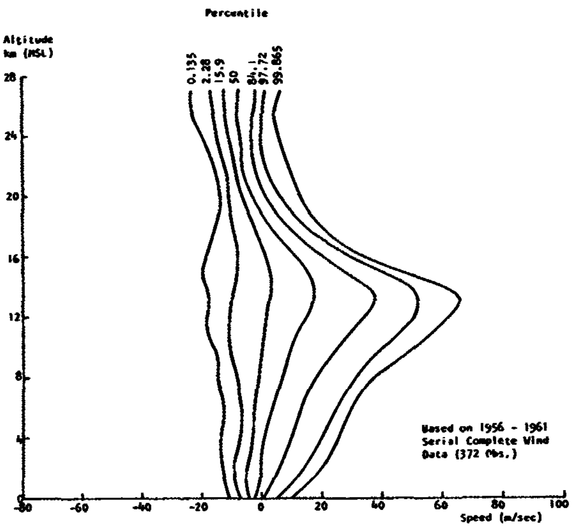


March

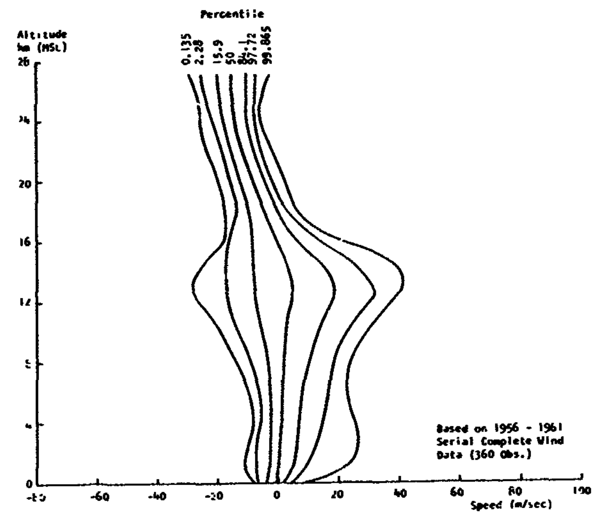


April

FIGURE 5.1 A. EMPIRICAL RANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 75° AND 255° FLIGHT AZIMUTHS -- JANUARY TO APRIL



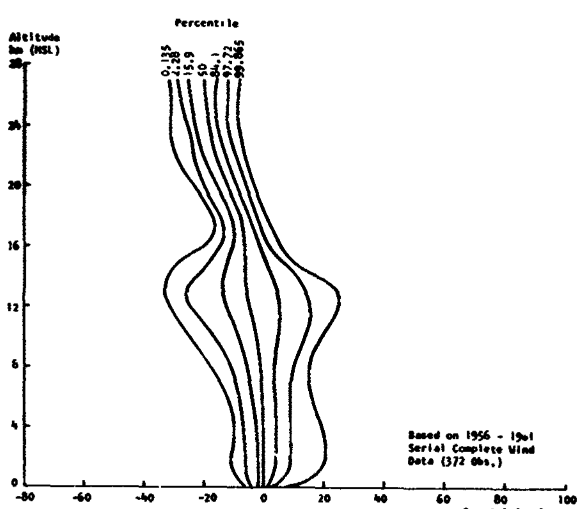
May



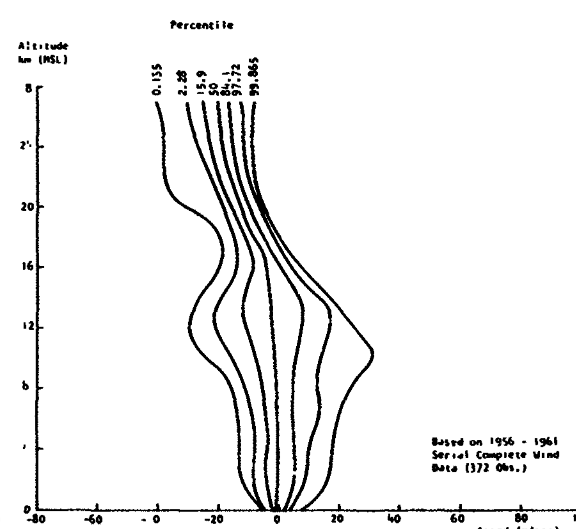
June

Legend:

1. For 75° Flight Azimuth
   Positive Values Tailwind
   Negative Values Headwind
2. For 255° Flight Azimuth
   Positive Values Headwind
   Negative Values Tailwind

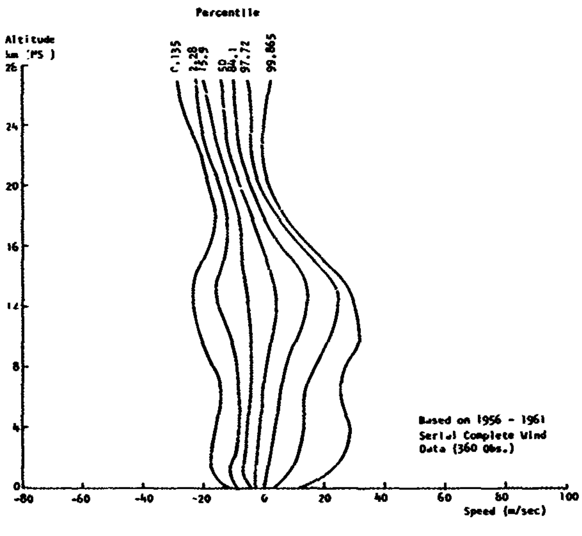


July

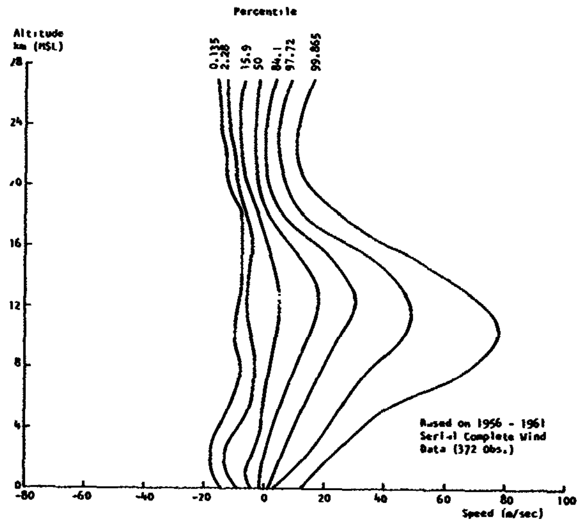


August

FIGURE 5.14B. EMPIRICAL RANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 75° AND 255° FLIGHT AZIMUTHS -- MAY TO AUGUST

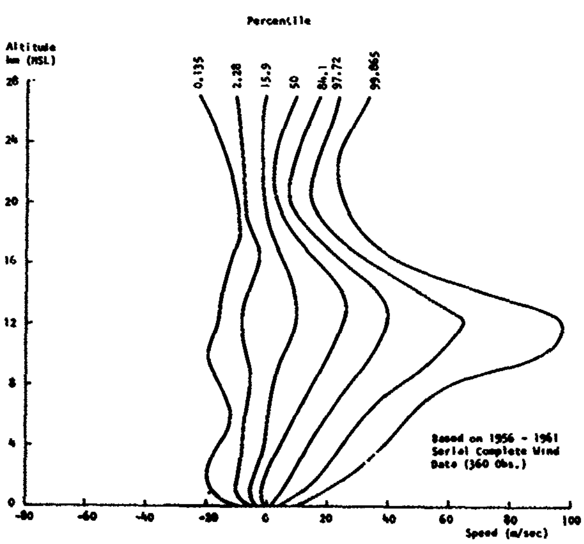


September

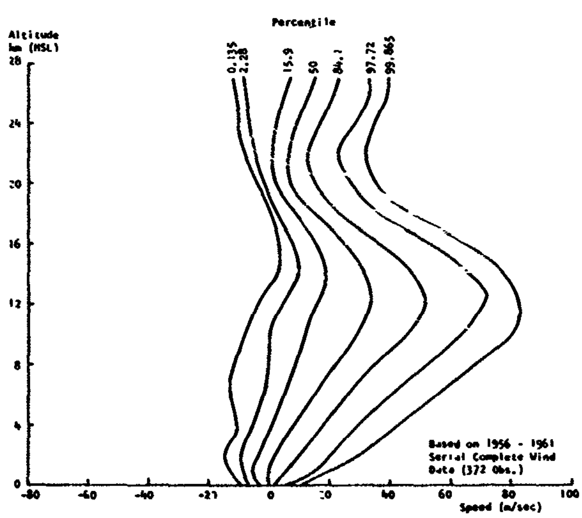


October

Legend:
1. For 75° Flight Azimuth
   Positive Values Tailwind
   Negative Values Headwind
2. For 255° Flight Azimuth
   Positive Values Headwind
   Negative Values Tailwind



November



December

FIGURE 5.14C. EMPIRICAL RANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 75° AND 225° FLIGHT AZIMUTHS -- SEPTEMBER TO DECEMBER

Legend:
1. For 75° Flight Azimuth
   Positive Values Tailwind
   Negative Values Headwind
2. For 255° Flight Azimuth
   Positive Values Headwind
   Negative Values Tailwind

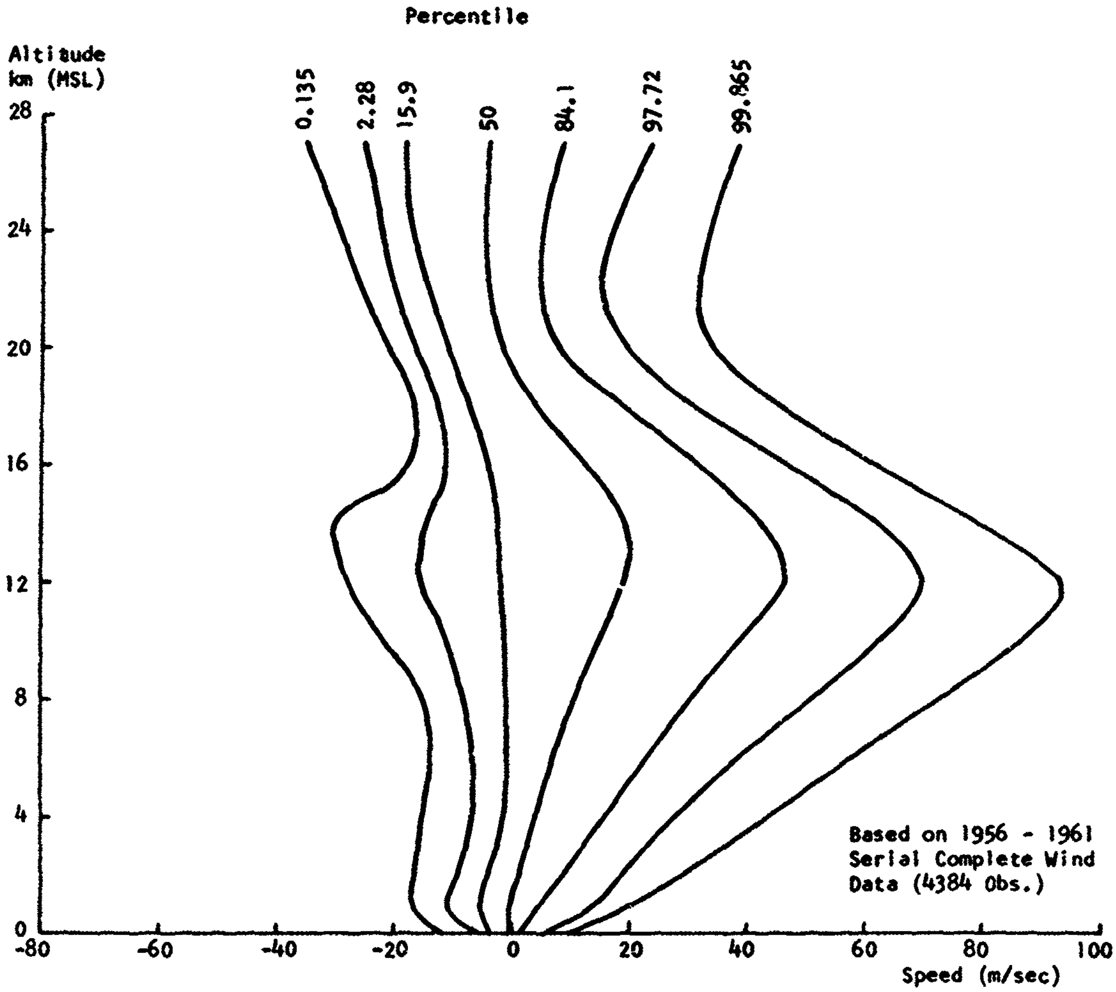
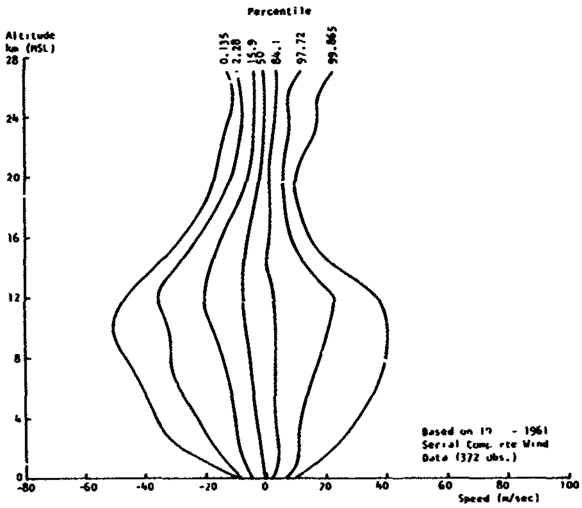
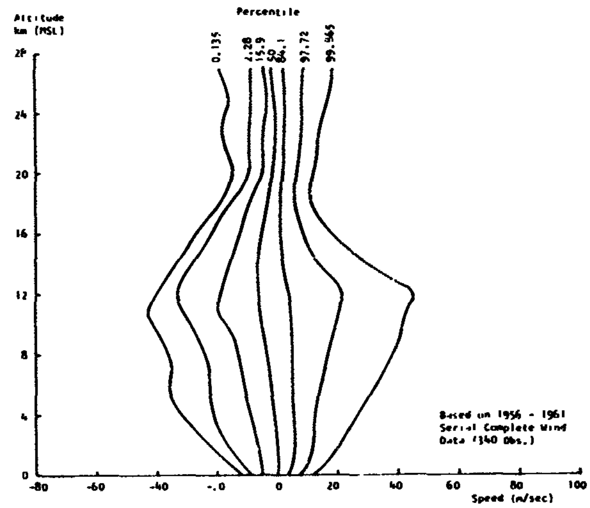


FIGURE 5.14D. EMPIRICAL RANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 75° AND 255° FLIGHT AZIMUTHS -- ANNUAL



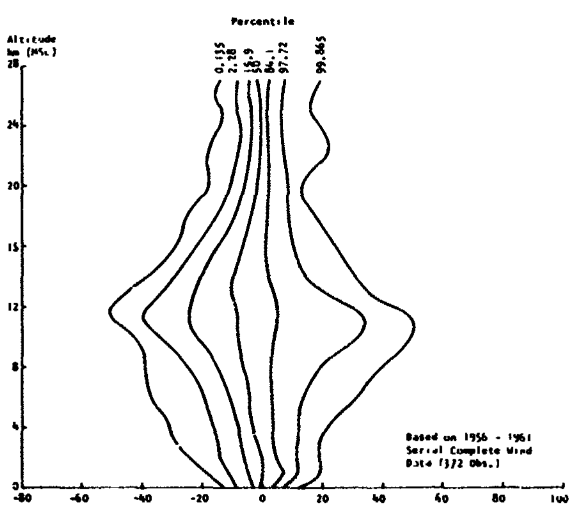
January



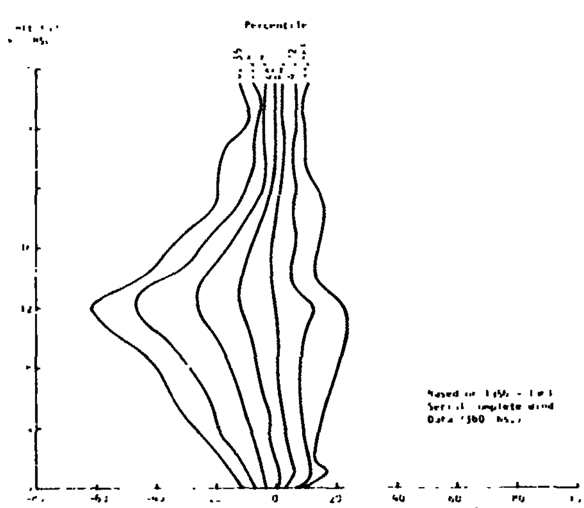
February

Legend:

1. For 75° Flight Azimuth
   Positive Values Wind from Right
   Negative Values Wind from Left
2. For 255° Flight Azimuth
   Positive Values Wind from Left
   Negative Values Wind from Right

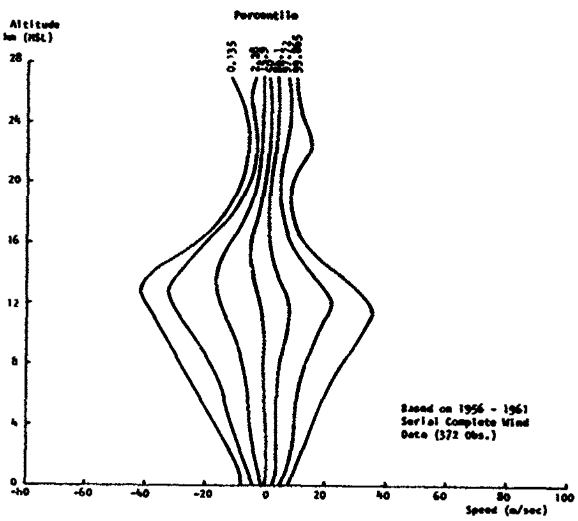


March

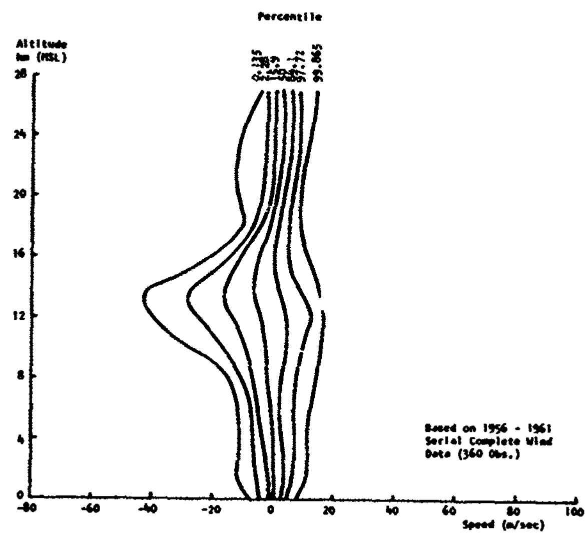


April

FIGURE 5.15A. EMPIRICAL <u>CROSSRANGE</u> WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 75° AND 255° FLIGHT AZIMUTHS -- JANUARY TO APRIL

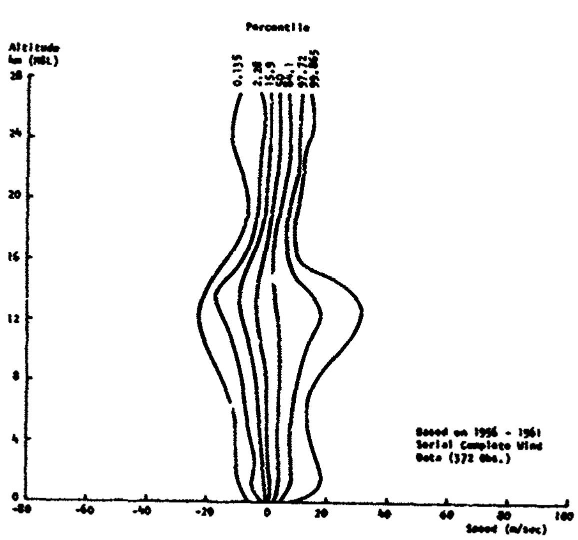


May

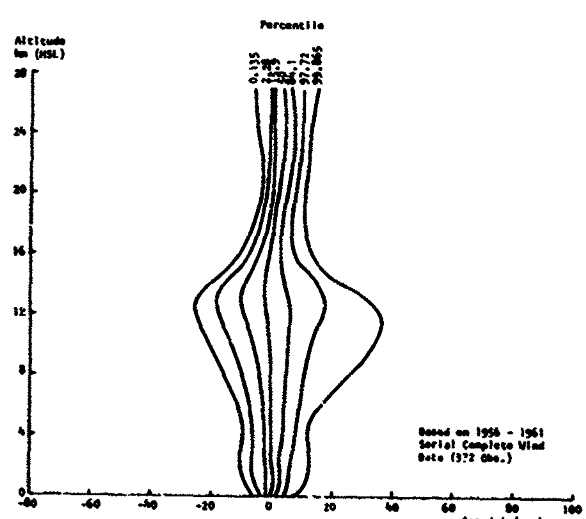


June

Legend:
1. For 75° Flight Azimuth
   Positive Values Wind from Right
   Negative Values Wind from Left
2. For 255° Flight Azimuth
   Positive Values Wind from Left
   Negative Values Wind from Right

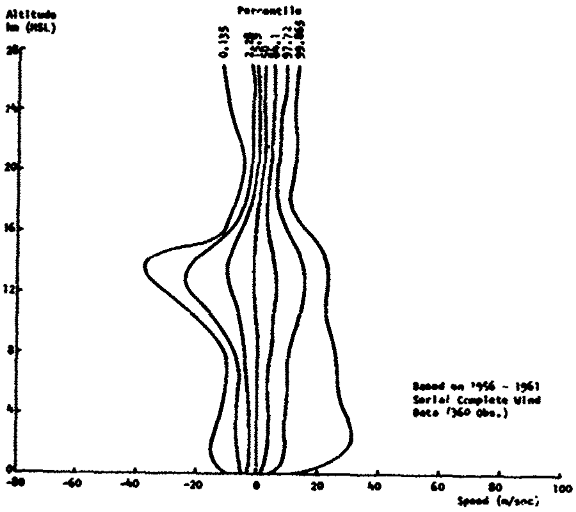


July

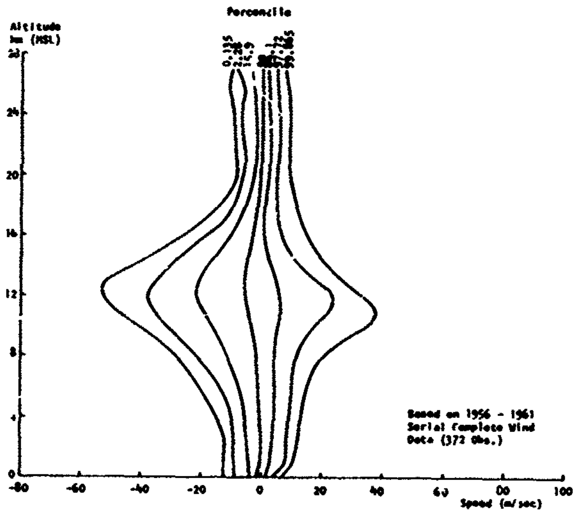


August

FIGURE 5.15B. EMPIRICAL CROSSRANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 75° AND 255° FLIGHT AZIMUTHS -- MAY TO AUGUST



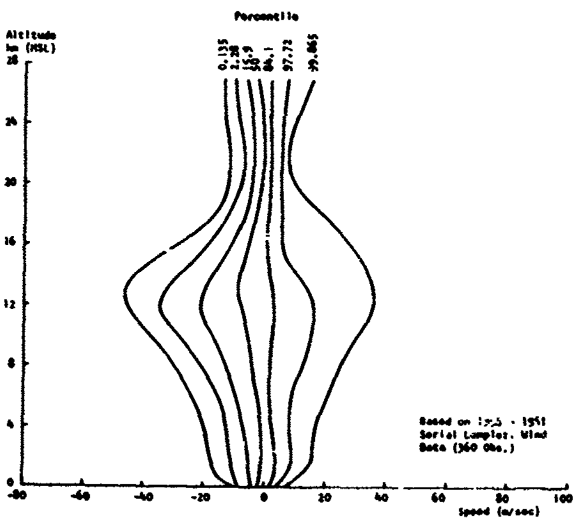
September



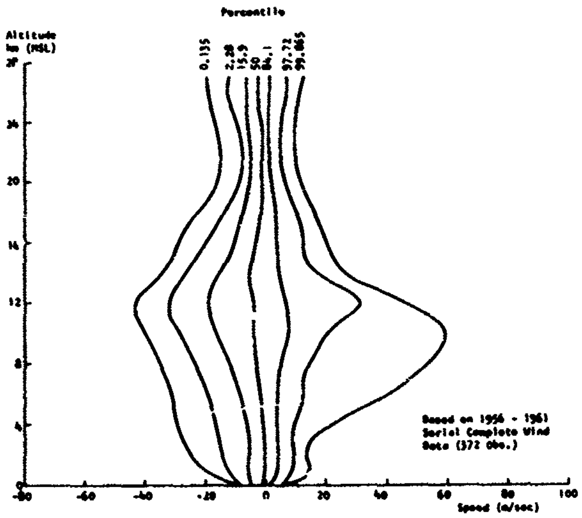
October

Legend:

1. For 75° Flight Azimuth
   Positive Values Wind from Right
   Negative Values Wind from Left
2. For 255° Flight Azimuth
   Positive Values Wind from Left
   Negative Values Wind from Right



November



December

FIGURE 5.15C. EMPIRICAL <u>CROSSRANGE</u> WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 75° AND 255° FLIGHT AZIMUTHS -- SEPTEMBER TO DECEMBER

Legend:

1. For 75° Flight Azimuth
   Positive Values Wind from Right
   Negative Values Wind from Left
2. For 255° Flight Azimuth
   Positive Values Wind from Left
   Negative Values Wind from Right

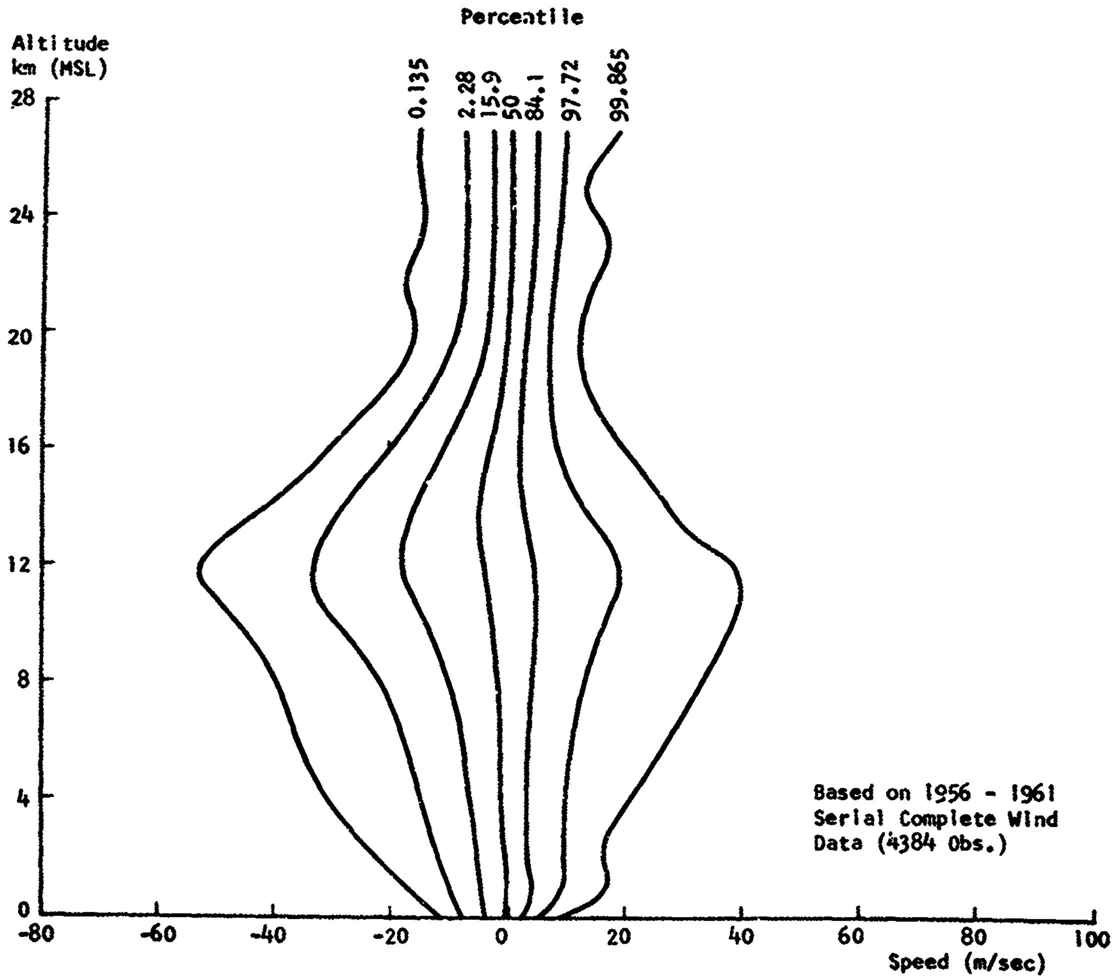
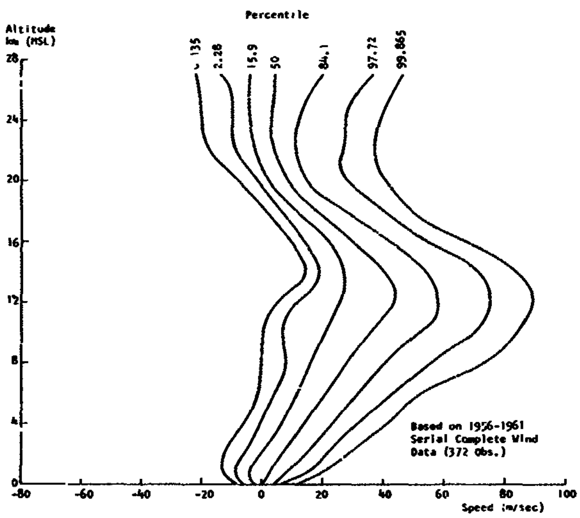
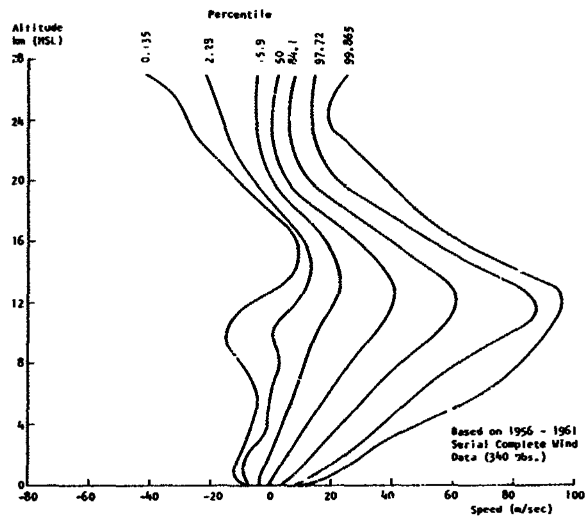


FIGURE 5.15D. EMPIRICAL CROSSRANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 75° AND 255° FLIGHT AZIMUTHS -- ANNUAL



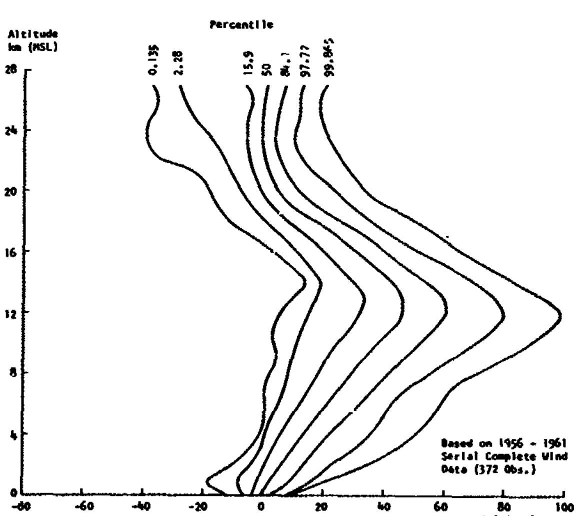
January



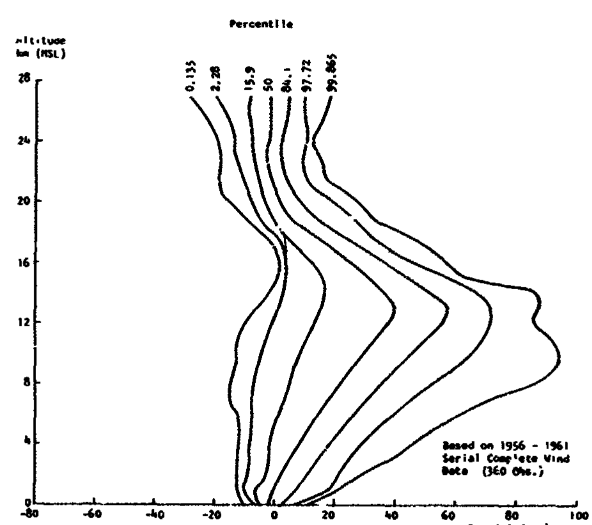
February

Legend:

1. For 90° Flight Azimuth
   Positive Values Tailwind
   Negative Values Headwind
2. For 270° Flight Azimuth
   Positive Values Headwind
   Negative Values Tailwind

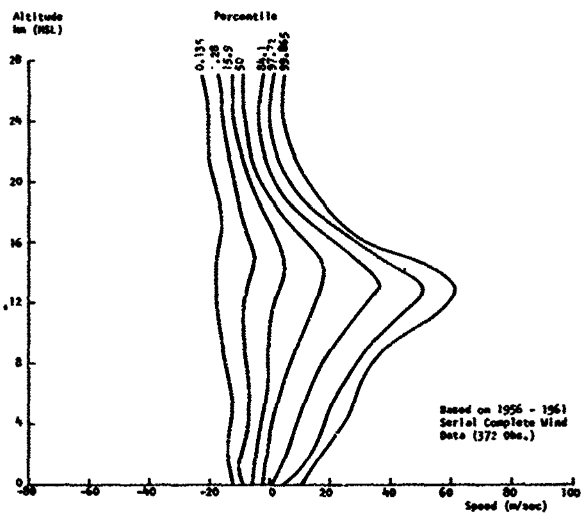


March

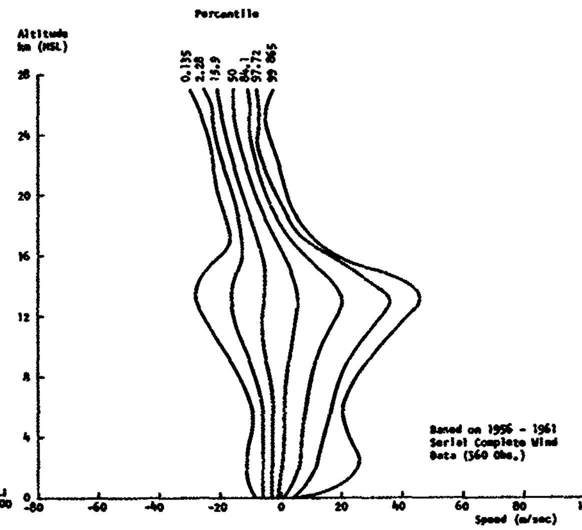


April

FIGURE 5.16A. EMPIRICAL RANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 90° AND 270° FLIGHT AZIMUTHS -- JANUARY TO APRIL



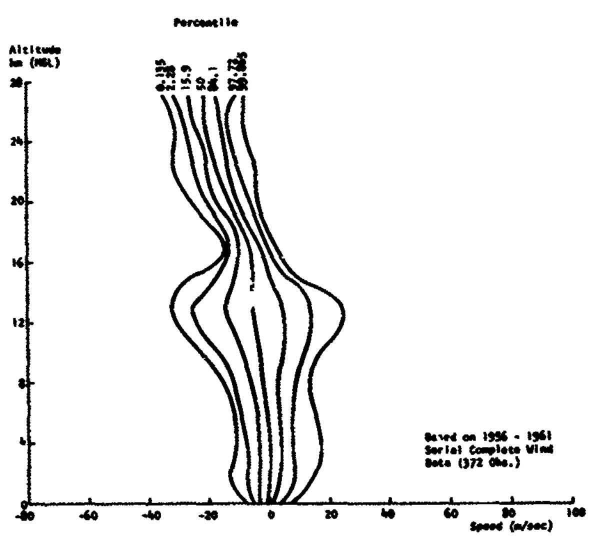
May



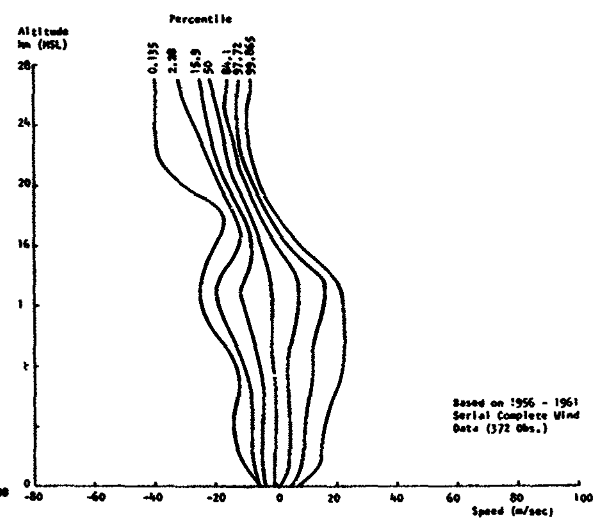
June

Legend:

1. For 90° Flight Azimuth
   Positive Values Tailwind
   Negative Values Headwind
2. For 270° Flight Azimuth
   Positive Values Headwind
   Negative Values Tailwind

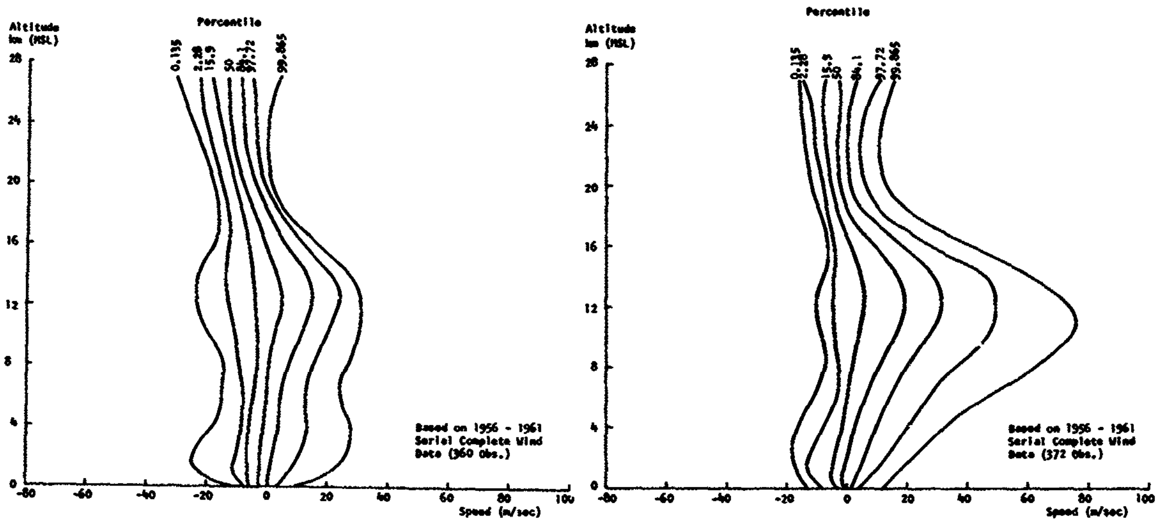


July



August

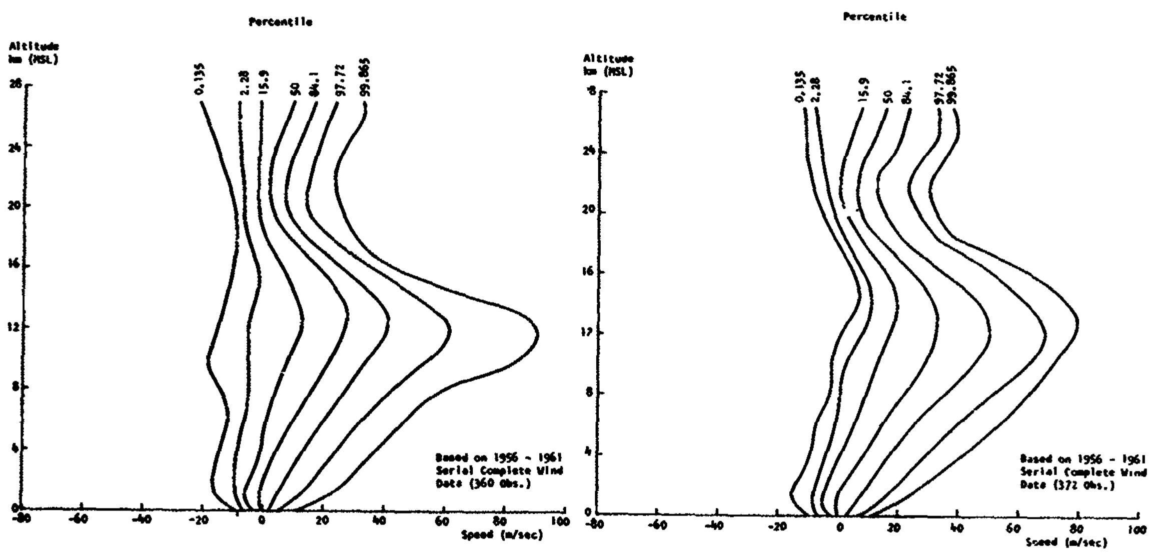
FIGURE 5.16B. EMPIRICAL RANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 90° AND 270° FLIGHT AZIMUTHS -- MAY TO AUGUST



September

October

Legend:
1. For 90° Flight Azimuth
   Positive Values Tailwind
   Negative Values Headwind
2. For 270° Flight Azimuth
   Positive Values Headwind
   Negative Values Tailwind



November

December

FIGURE 5.16C. EMPIRICAL RANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 90° AND 270° FLIGHT AZIMUTHS -- SEPTEMBER TO DECEMBER

Legend:
1. For 90° Flight Azimuth
   Positive Values Tailwind
   Negative Values Headwind
2. For 270° Flight Azimuth
   Positive Values Headwind
   Negative Values Tailwind

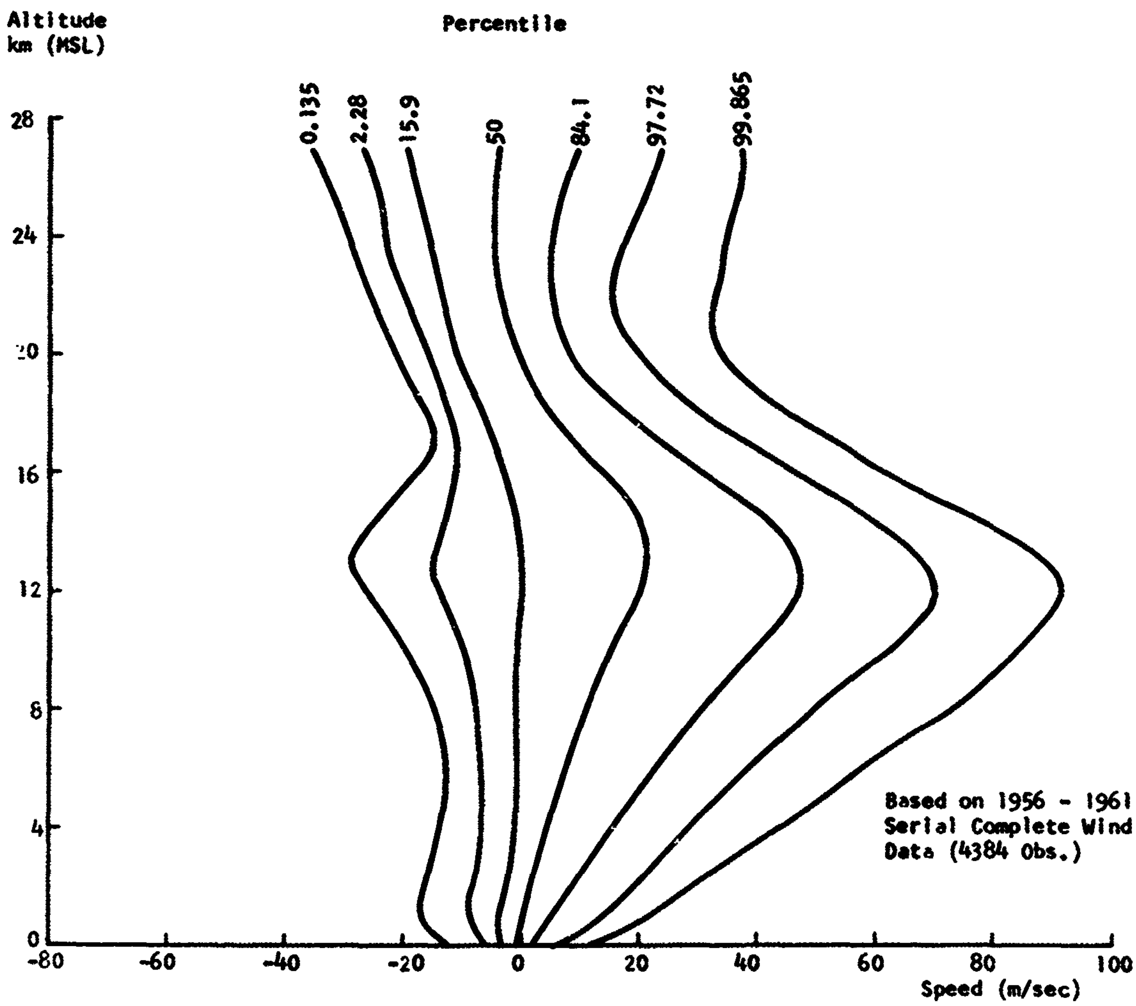
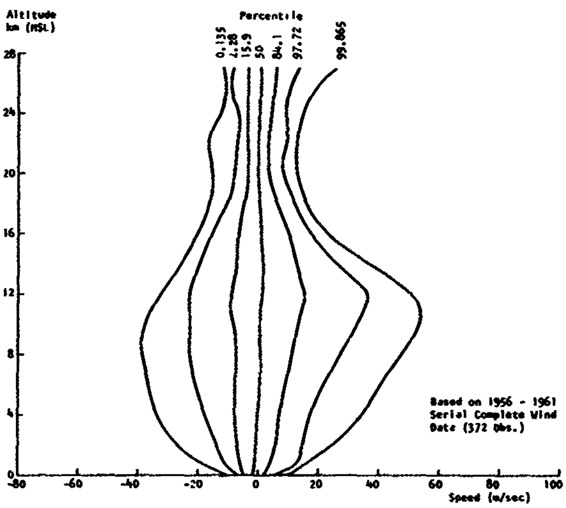
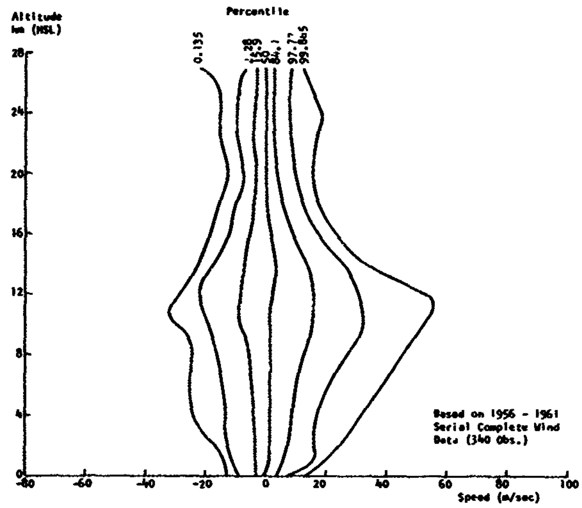


FIGURE 5.16D. EMPIRICAL <u>RANGE</u> WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 90° AND 270° FLIGHT AZIMUTHS -- ANNUAL



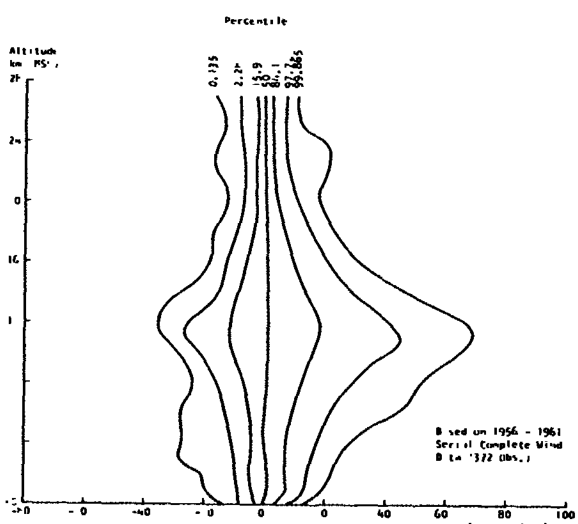
January



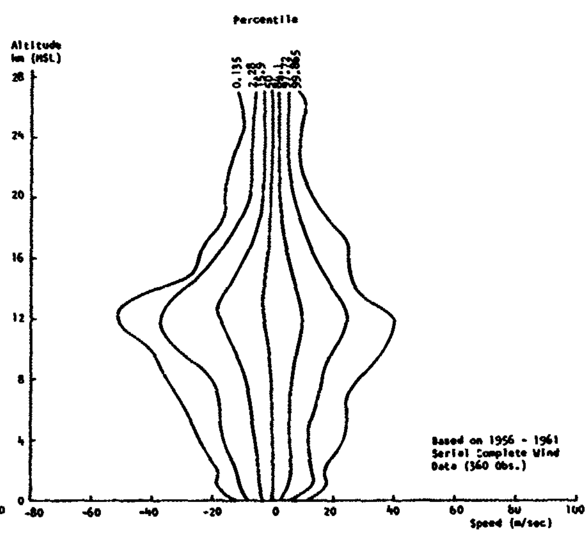
February

Legend:

1. For 90° Flight Azimuth
   Positive Values Wind from Right
   Negative Values Wind from Left
2. For 270° Flight Azimu:h
   Positive Values Wind from Left
   Negative Values Wind from Right

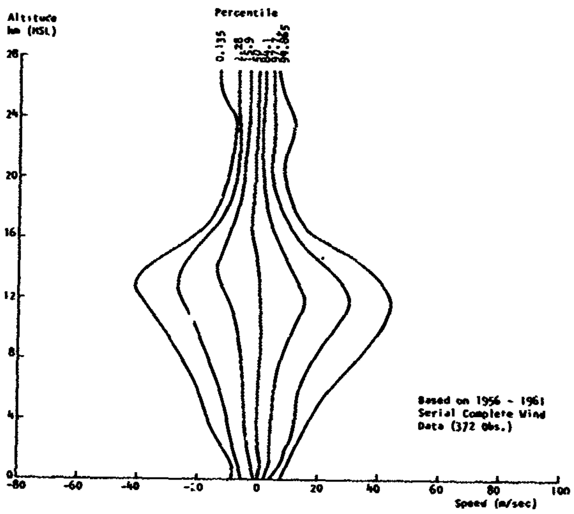


March

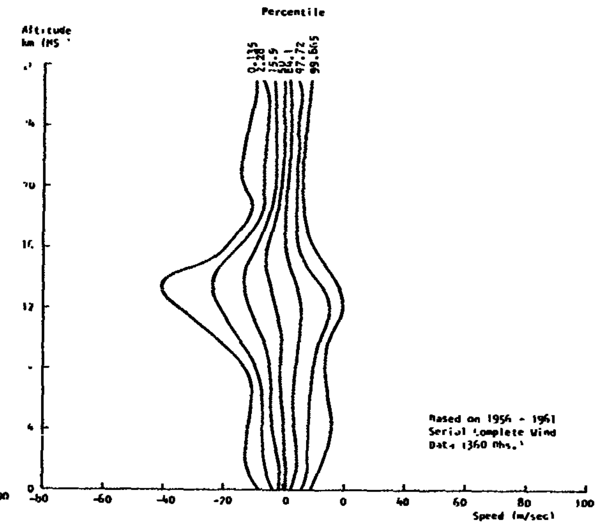


April

FIGURE 5.17A. EMPIRICAL CROSSRANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 90° AND 270° FLIGHT AZIMUTHS -- JANUARY TO APRIL



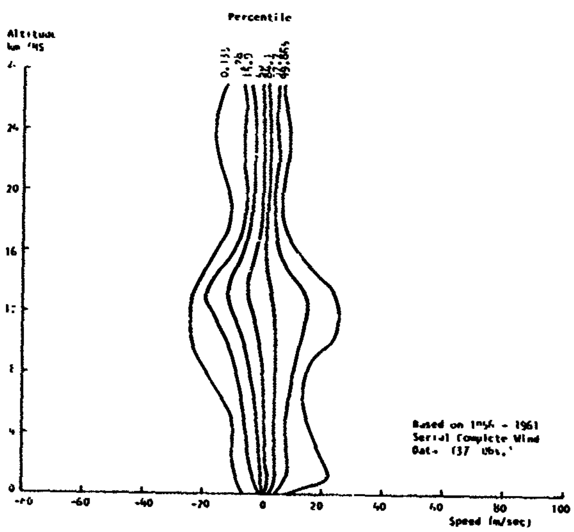
M



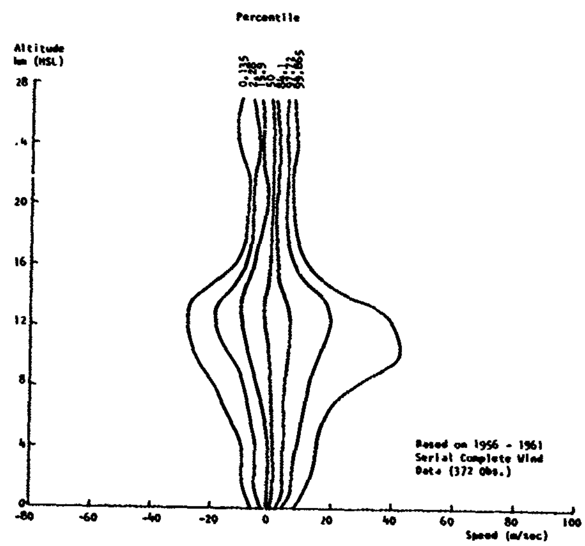
June

Legend:

1. For 90° Flight Azimuth
   Positive Values Wind from Right
   Negative Values Wind from Left
2. For 270° Flight Azimuth
   Positive Values Wind from Left
   Negative Values Wind from Right

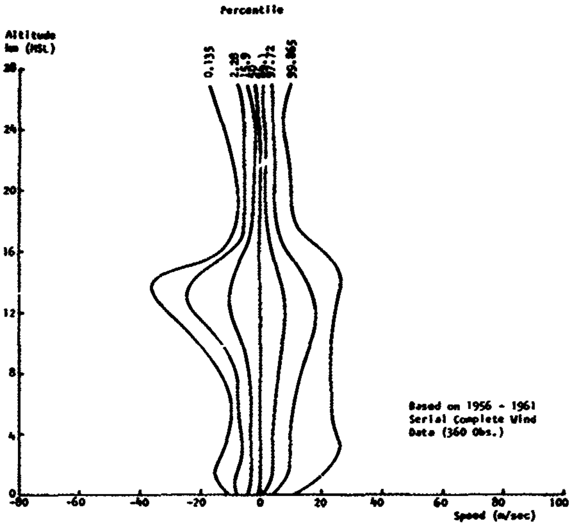


July

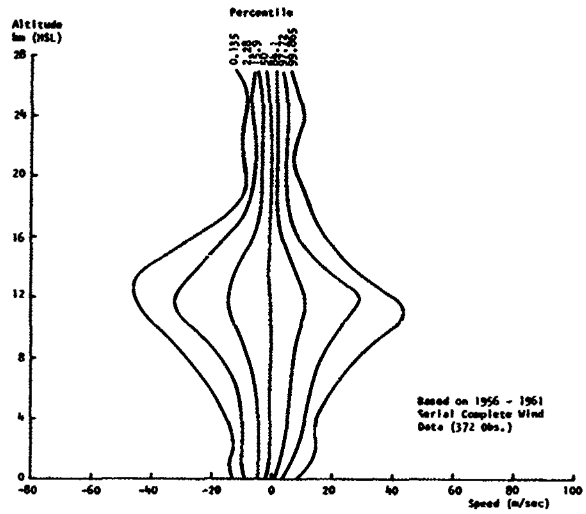


August

FIGURE 5.17B. EMPIRICAL CROSSRANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 90° AND 270° FLIGHT AZIMUTHS -- MAY TO AUGUST

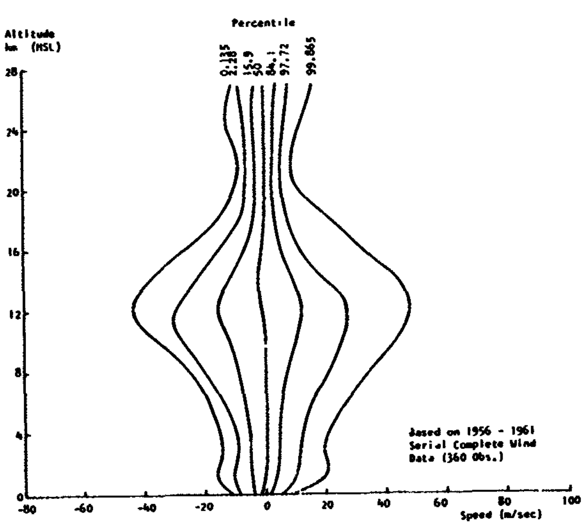


September

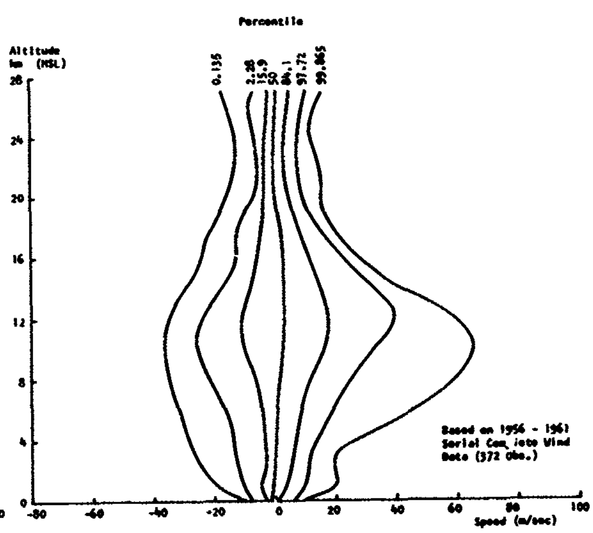


October

Legend:
1. For 90° Flight Azimuth
   Positive Values Wind from Right
   Negative Values Wind from Left
2. For 270° Flight Azimuth
   Positive Values Wind from Left
   Negative Values Wind from Right



November



December

FIGURE 5.17C. EMPIRICAL CROSSRANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 90° AND 270° FLIGHT AZIMUTHS -- SEPTEMBER TO DECEMBER

Legend:
1. For 90° Flight Azimuth
   Positive Values Wind from Right
   Negative Values Wind from Left
2. For 270° Flight Azimuth
   Positive Values Wind from Left
   Negative Values Wind from Right

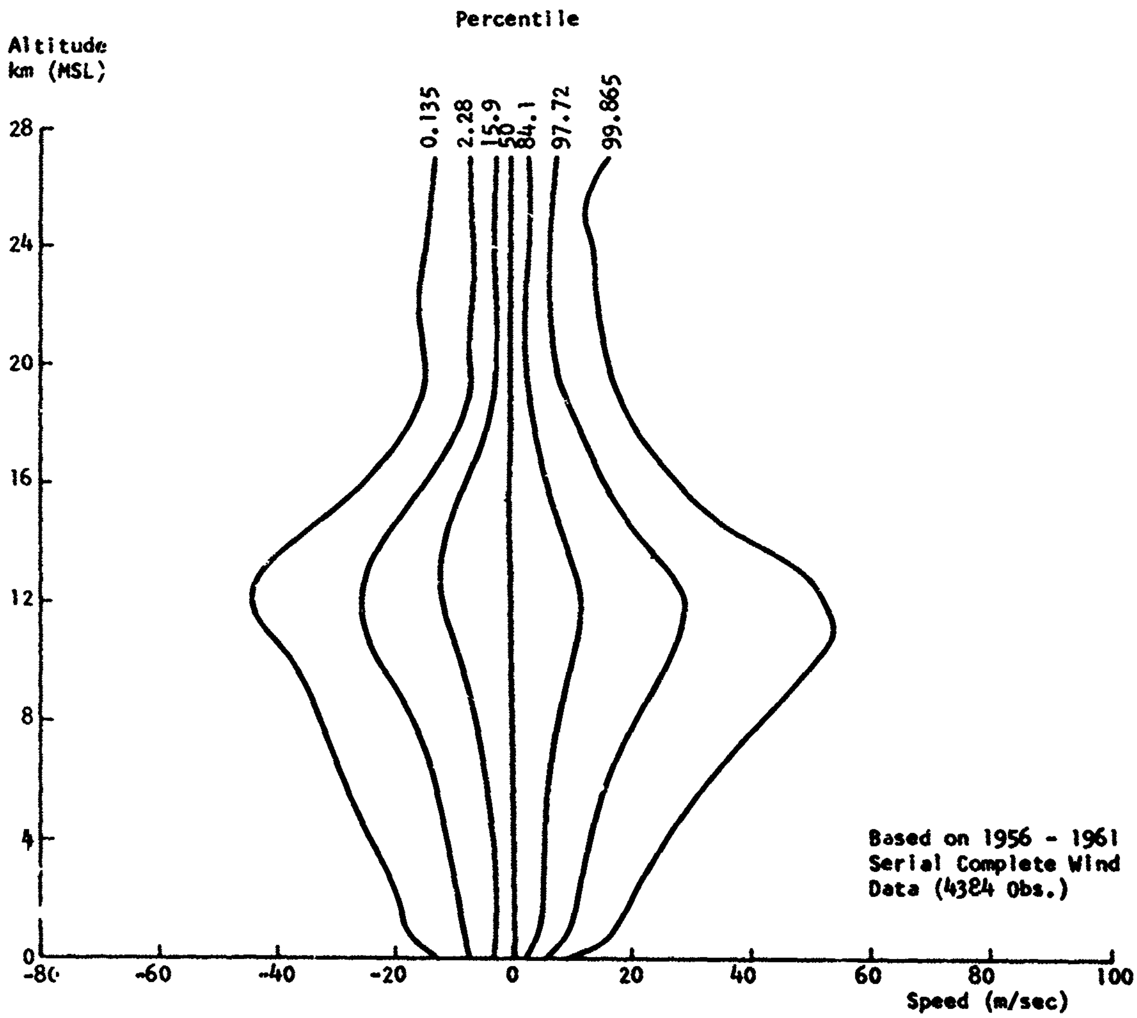
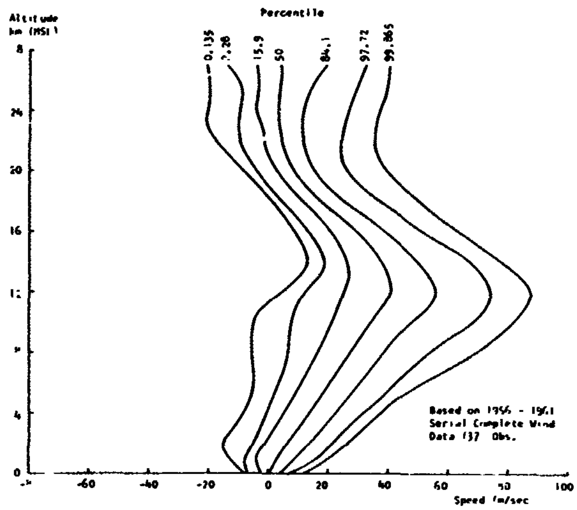
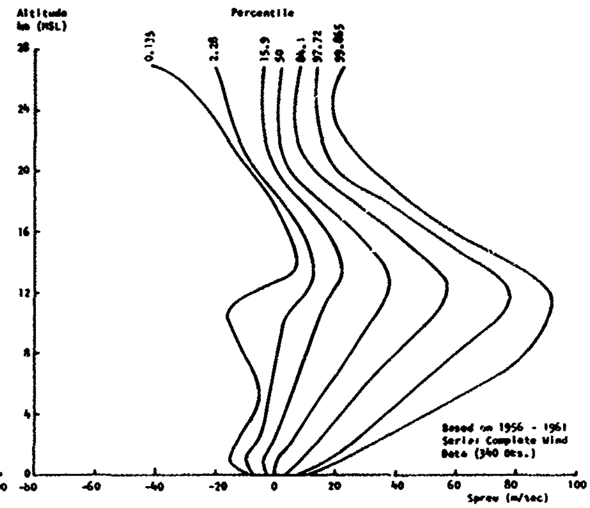


FIGURE 5.17D. EMPIRICAL CROSSRANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 90° AND 270° FLIGHT AZIMUTHS -- ANNUAL



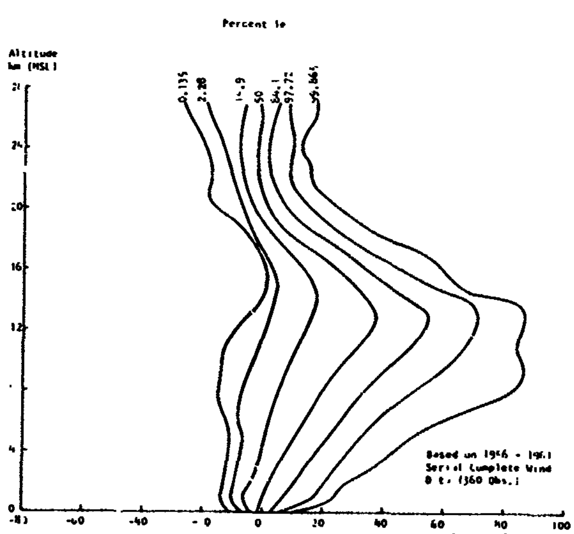
January



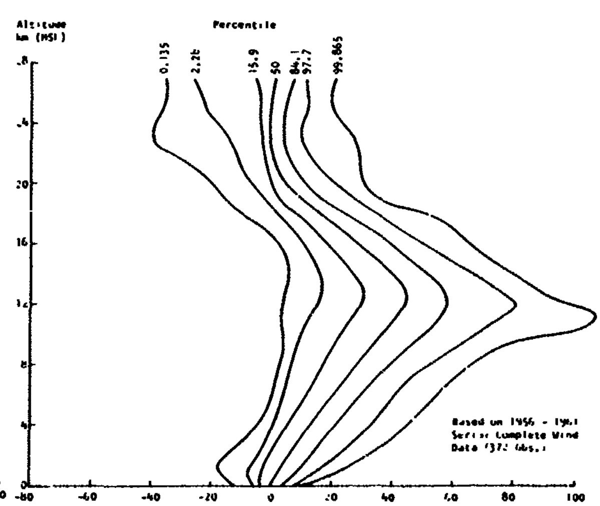
February

Legend:

1. For 105° Flight Azimuth
   Positive Values Tailwind
   Negative Values Headwind
2. For 285° Flight Azimuth
   Positive Values Headwind
   Negative Values Tailwind

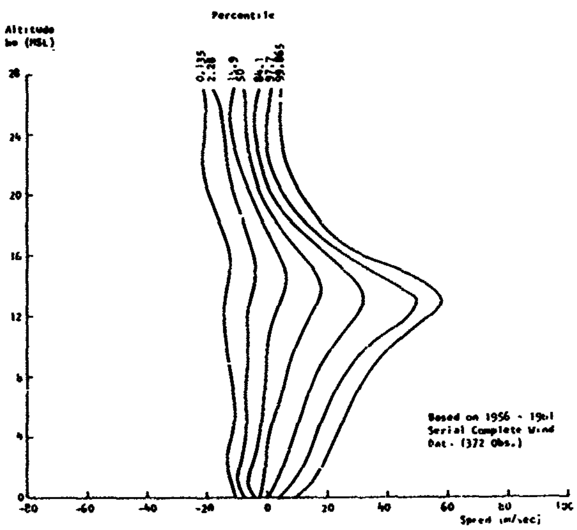


March

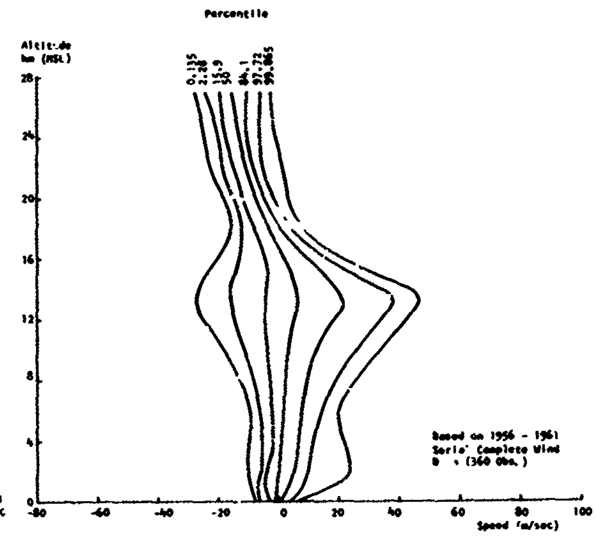


April

FIGURE 5.18A. EMPIRICAL <u>RANGE</u> WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 105° AND 285° FLIGHT AZIMUTHS -- JANUARY TO APRIL



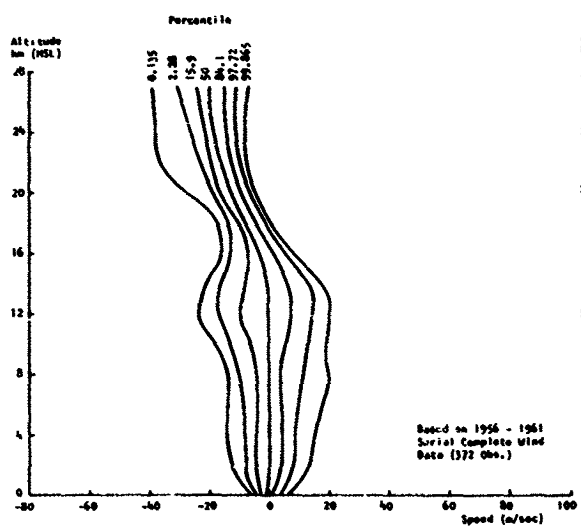
May



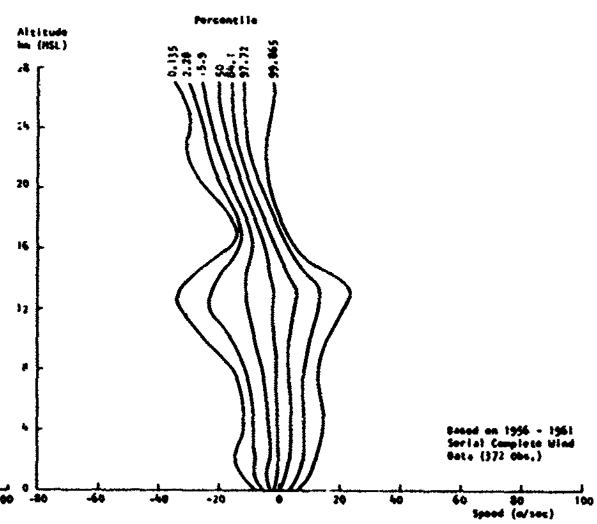
June

Legend:

1. For 105° Flight Azimuth
   Positive Values Tailwind
   Negative Values Headwind
2. For 285° Flight Azimuth
   Positive Values Headwind
   Negative Values Tailwind

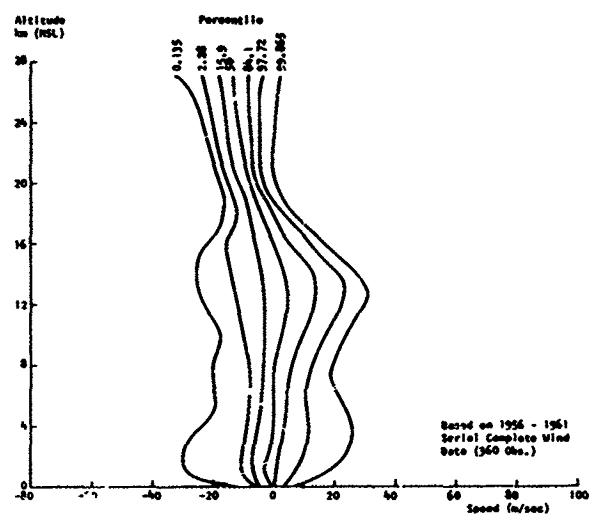


July

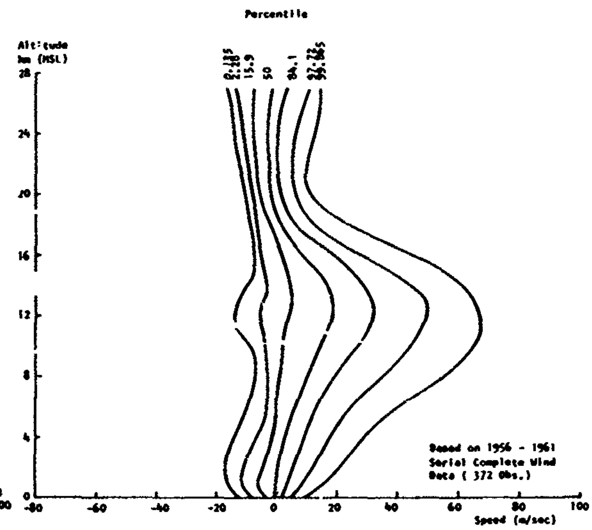


August

FIGURE 5.18B. EMPIRICAL RANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 105° AND 285° FLIGHT AZIMUTHS -- MAY TO AUGUST

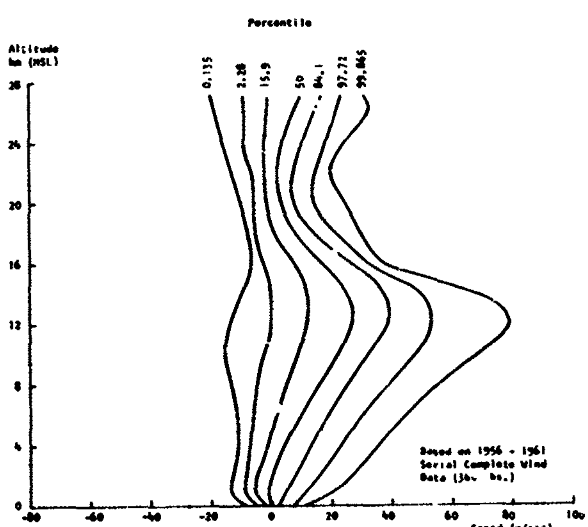


September

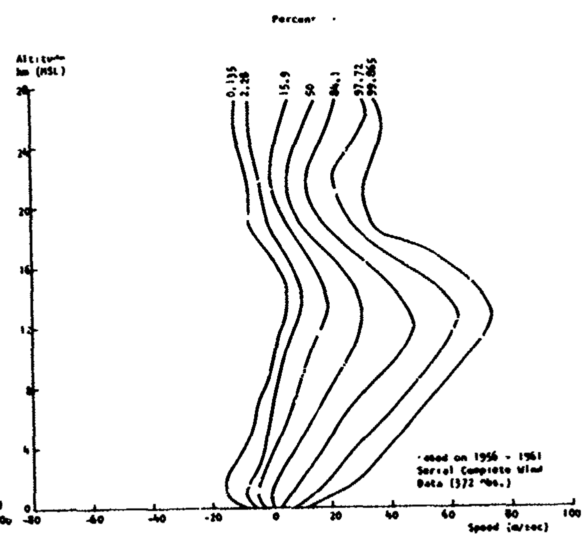


October

Legend:
1. For 105° Flight Azimuth
   Positive Values Tailwind
   Negative Values Headwind
2. For 285° Flight Azimuth
   Positive Values Headwind
   Negative Values Tailwind



November



December

FIGURE 5.18C. EMPIRICAL RANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 105° AND 285° FLIGHT AZIMUTHS -- SEPTEMBER TO DECEMBER

Legend:
1. For 105° Flight Azimuth
   Positive Values Tailwind
   Negative Values Headwind
2. For 285° Flight Azimuth
   Positive Values Headwind
   Negative Values Tailwind

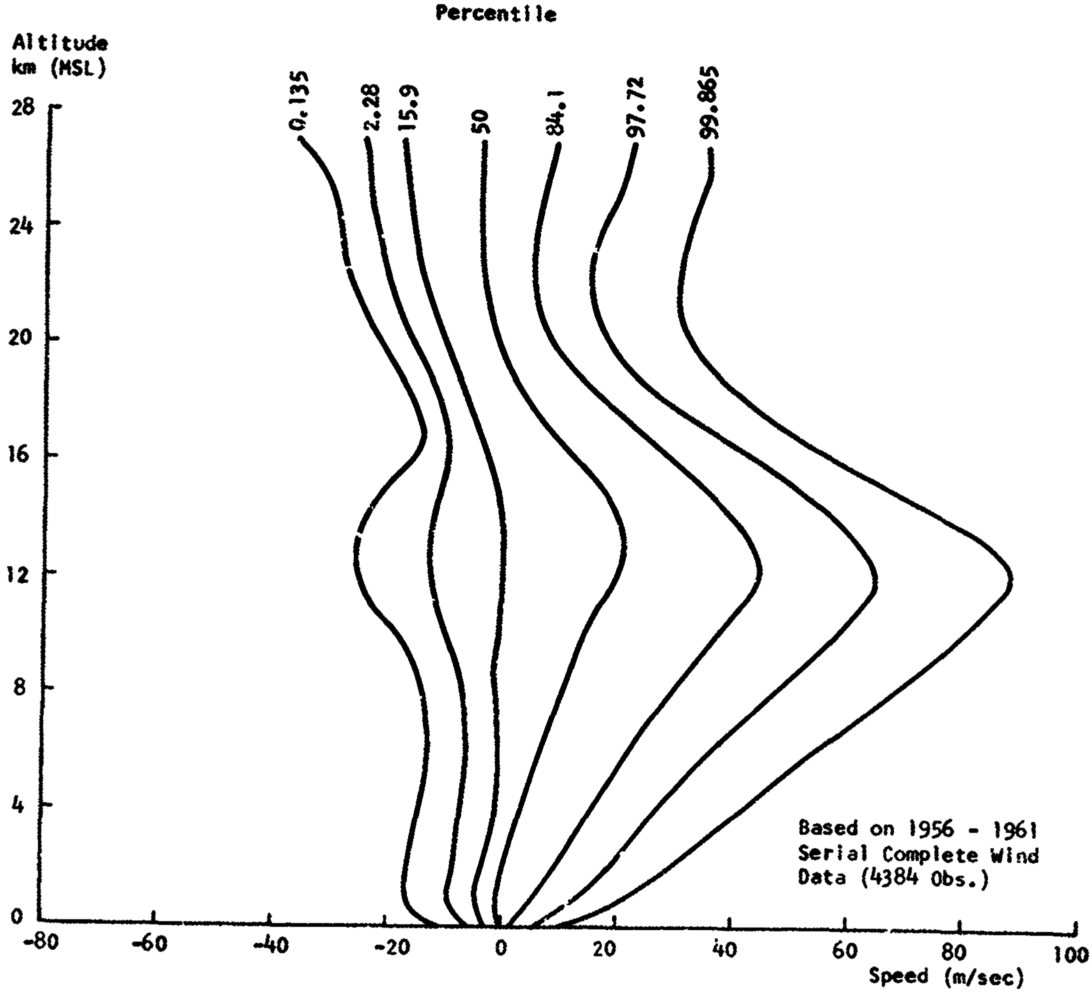
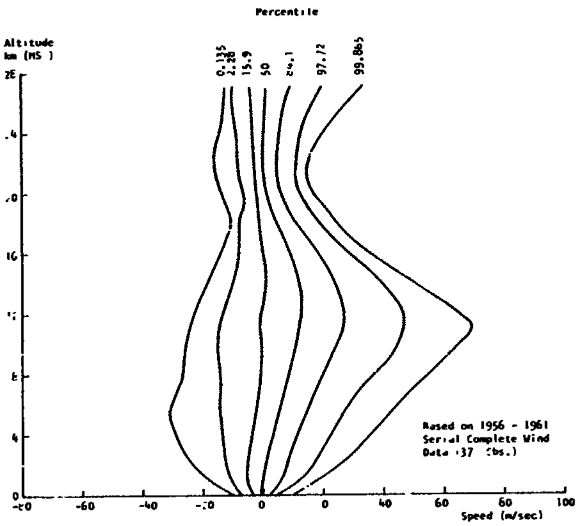
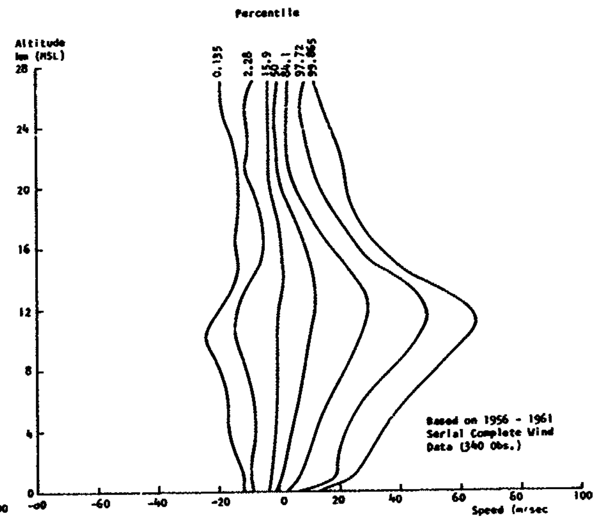


FIGURE 5.18D. EMPIRICAL RANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 105° AND 285° FLIGHT AZIMUTHS -- ANNUAL

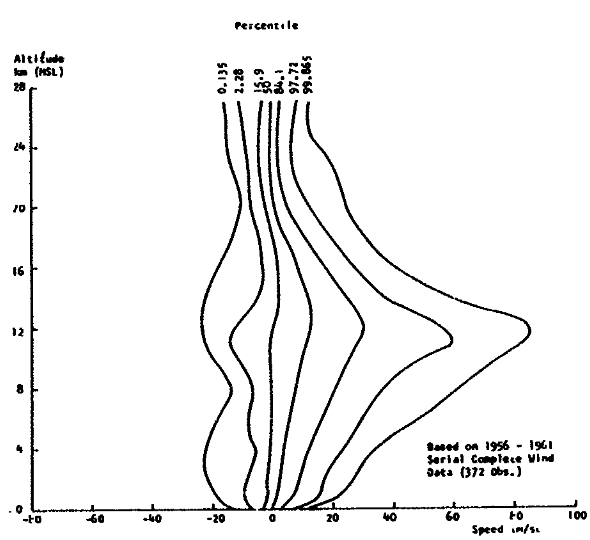


January

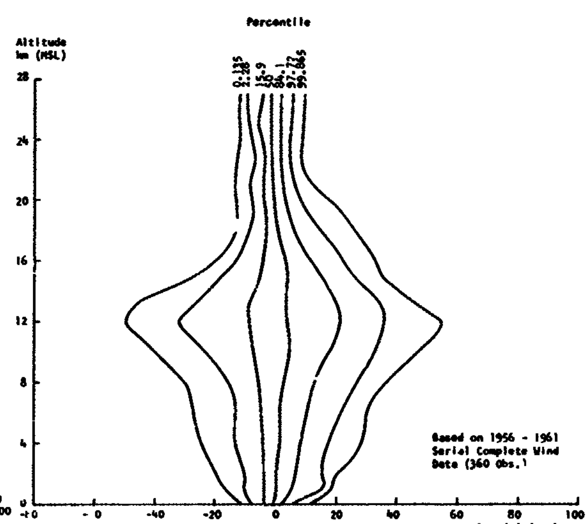


February

Legend:
1. For 105° Flight Azimuth
   Positive Values Wind from Right
   Negative Values Wind from Left
2 For 285° Flight Azimuth
   Positive Values Wind from Left
   Negative Values Wind from Right

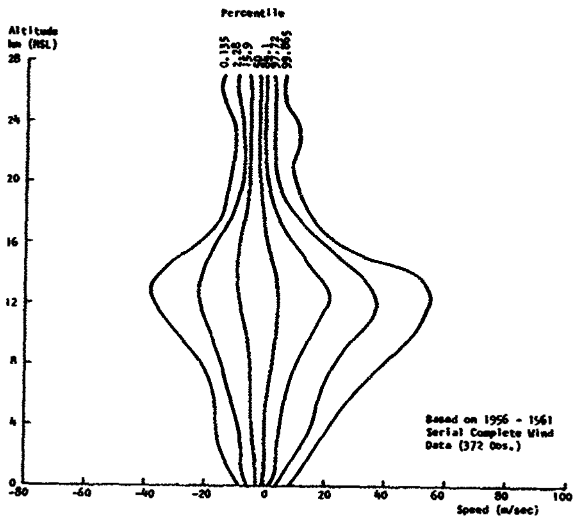


March

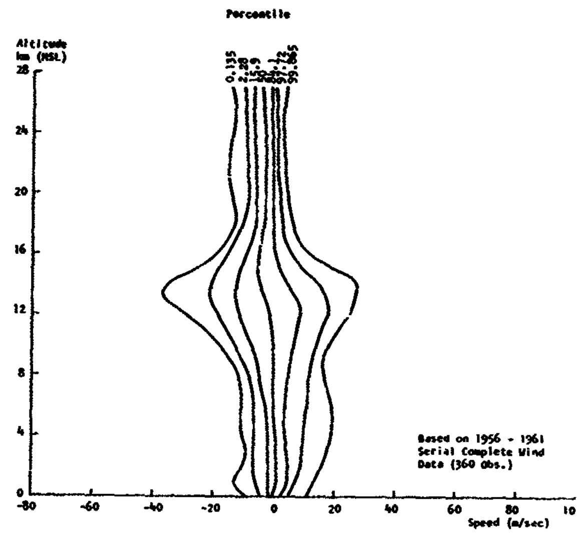


April

FIGURE 5.19A. EMPIRICAL <u>CROSSRANGE</u> WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 105° AND 285° FLIGHT AZIMUTHS -- JANUARY TO APRIL



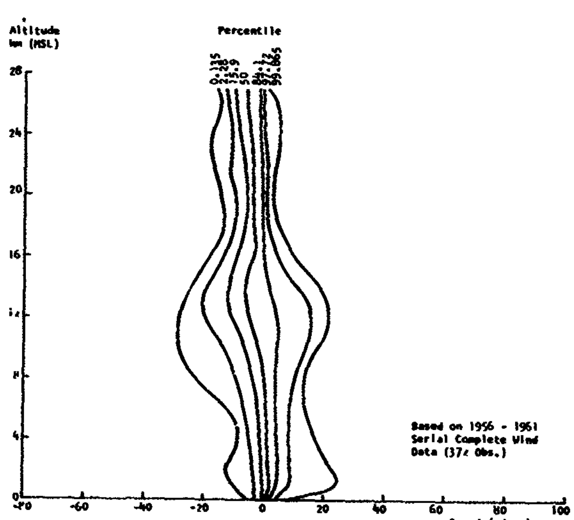
May



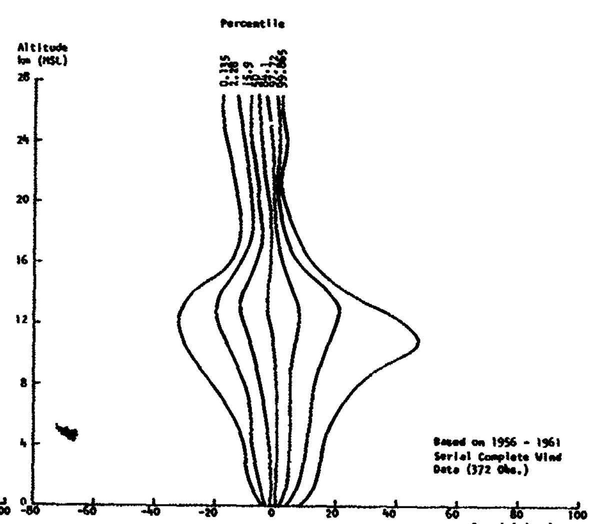
June

Legend:

1. For 105° Flight Azimuth
   Positive Values Wind from Right
   Negative Values Wind from Left
2. For 285° Flight Azimuth
   Positive Values Wind from Left
   Negative Values Wind from Right

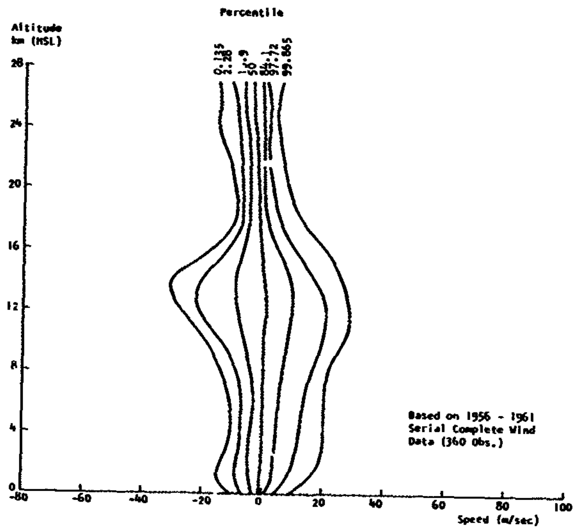


July

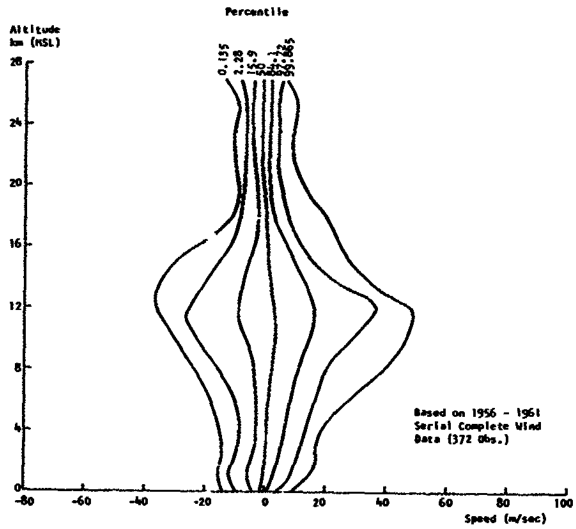


August

FIGURE 5.19B. EMPIRICAL CROSSRANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 105° AND 285° FLIGHT AZIMUTHS -- MAY TO AUGUST

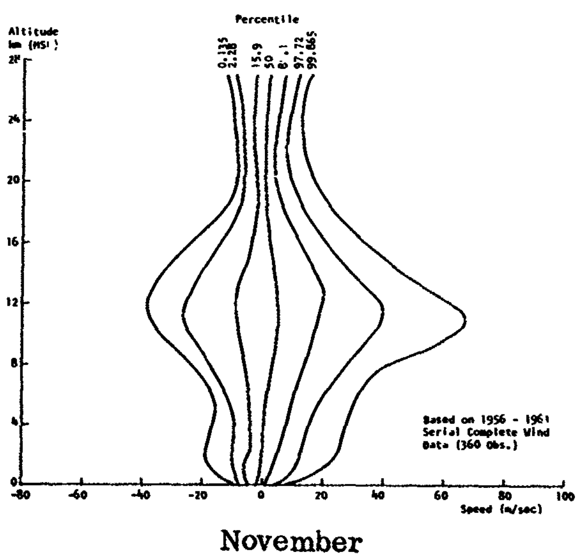


September

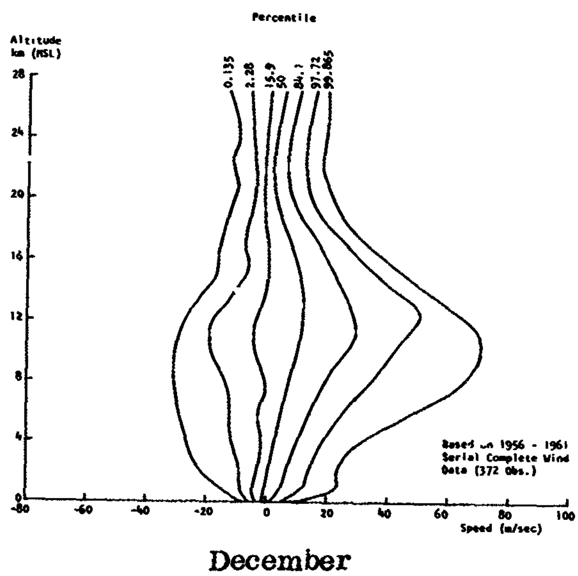


October

Legend:
1. For 105° Flight Azimuth
   Positive Values Wind from Right
   Negative Values Wind from Left
2. For 285° Flight Azimuth
   Positive Values Wind from Left
   Negative Values Wind from Right



November



December

FIGURE 5.19C. EMPIRICAL CROSSRANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 105° AND 285° FLIGHT AZIMUTHS -- SEPTEMBER TO DECEMBER

Legend:
1. For 105° Flight Azimuth
   Positive Values Wind from Right
   Negative Values Wind from Left
2. For 285° Flight Azimuth
   Positive Values Wind from Left
   Negative Values Wind from Right

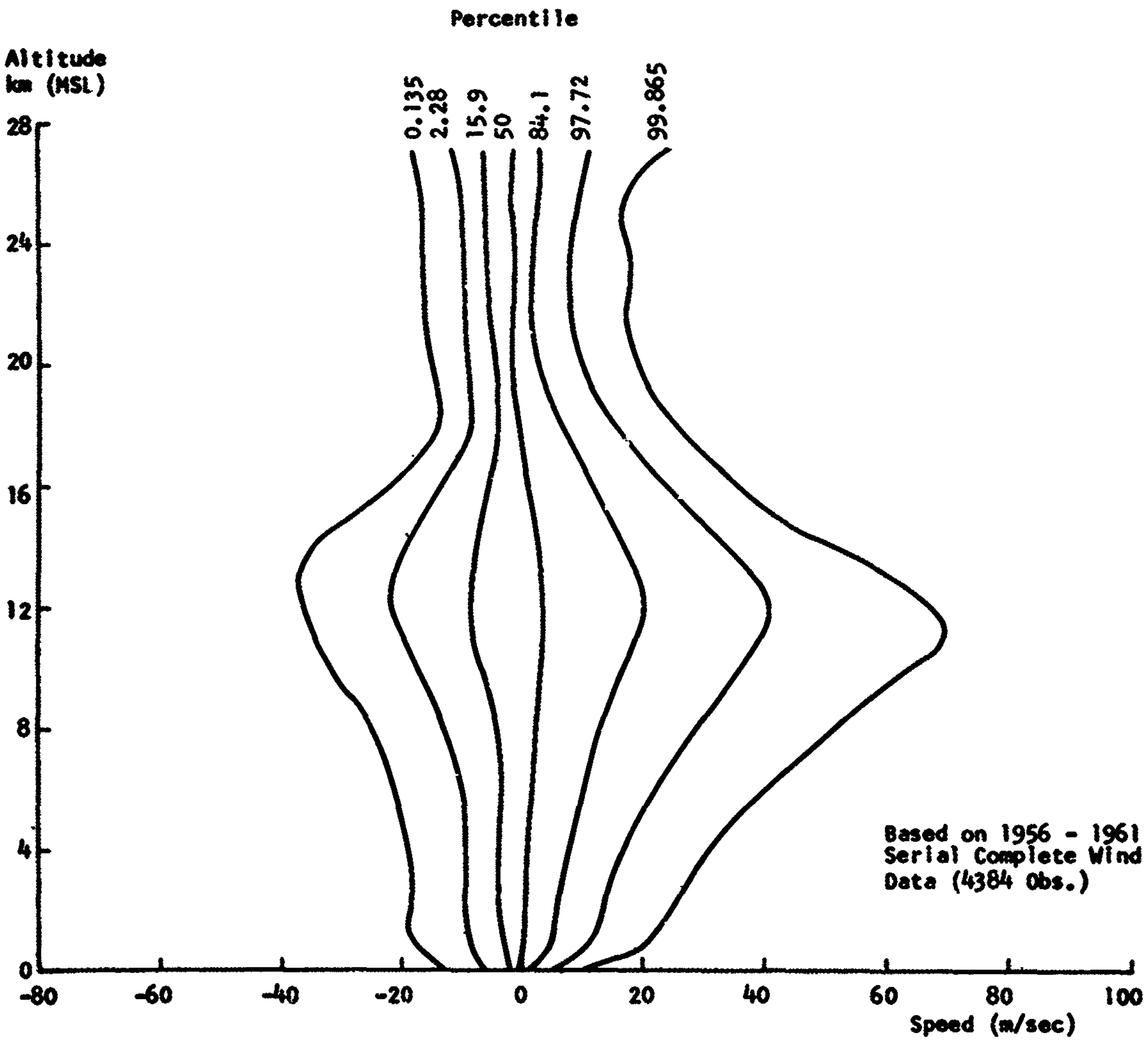


FIGURE 5.19D. EMPIRICAL CROSSRANGE WIND PROFILE ENVELOPES FOR CAPE KENNEDY (ETR), FLORIDA FOR 105° AND 285° FLIGHT AZIMUTHS -- ANNUAL

5.2.7 Synthetic Wind Profile.

A synthetic wind profile is an attempt to substitute one representative wind profile for a multitude of measured or statistically defined wind profiles and to insure an adequate vehicle design based on the established design philosophy. This is to keep manpower and computer requirements for analysis of vehicle responses in acceptable limits. As new information is gained, or as the vehicle systems change, updating of the design wind profile and/or design philosophy is required. Currently, studies are being conducted to provide a more general statistical description of the wind environment employing non-stationary statistical concepts and the newer FPS-16 radar Jimsphere wind profiles.

Synthetic wind profiles for space vehicle design are usually based on quasi-steady-state wind speeds, wind shears, and gusts. These are combined to represent physically reasonable conditions which will insure a high probability of success when the vehicle is launched.

5.2.7.1 Idealized Wind Speed Envelopes.

Examples of idealized wind speed envelopes used in defining synthetic wind profiles are given in Section 5.2.4.1, Figures 5.10 thru 5.13. These profiles represent envelopes of quasi-steady-state wind speeds at each point on the profile for a given probability level. For example, the 95 percentile envelope represents wind speeds that will not be exceeded more than 5 percent of the time* during some specified reference period. In this report a monthly reference period is used. The profile envelopes represent wind conditions for the given percentile level and for the windiest monthly reference period. This means that the envelope values will be exceeded by the specified percentage during only one month - the windiest month. During the other 11 months, the wind speeds represented by a given percentile envelope should be less. The 95 percentile envelope shown in Figure 5.10 has been employed in constructing synthetic wind profiles for use in numerous space vehicle design studies, and will be used in this section to illustrate the construction of synthetic profiles. Any other percentile envelope may be used in an analogous manner.

5.2.7.2 Wind Shear and Wind Speed Change.

The data in this section provide representative information on the wind shear and associated wind speed change for altitude layers (scale-of-distance) of 100 meters to 5,000 meters. Wind shear is defined as the wind speed change over an altitude interval divided by the interval. Wind speed change or wind buildup rate is obtained by multiplying the wind shear by the appropriate scale-of-distance. Values of wind speed change or wind shear for a vehicle with other

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* In the terms of risk this means that for any individual measurement selected at random during the reference period, there is a 5 percent risk that the measurement will be greater than the 95 percentile envelope wind speed value, relative to the data sample employed in this analysis.

than a vertical flight path are found by multiplying the shear or wind speed change by the cosine of the angle between the vertical axis and the vehicle trajectory.

An envelope of the 99 percentile wind speed change or shear is used in constructing synthetic wind profiles. This envelope is not meant to imply perfect correlation between the shears for the various scales-of-distance. Certain correlations do exist depending upon the scale-of-distance and the wind speed magnitudes considered. Research is being conducted to establish more quantitative data on these relationships. A brief treatment of this subject is given in Section 5.2.7.5.

Wind shear statistics for the various locations vary somewhat, partly due to data sample size, accuracy of basic data, prevailing meteorological conditions, and orographic features. For the purpose of this document, one basic set of data on wind shear and wind buildup rates has been employed and is considered to be representative for all locations.* Tables 5.15 and 5.16 and Figures 5.20 and 5.21 provide the data on wind shear and wind buildup rates.

5.2.7.3 Gust.

The quasi-steady-state inflight wind speed envelopes presented in Section 5.2.4.1 of this report do not contain gust (high frequency content) of the wind profile. The quasi-steady-state wind profile measurements have been defined as those obtained by the rawinsonde system (see Section 5.2.2.1). These measurements represent wind speeds averaged over approximately 600 meters in the vertical and, therefore, eliminate features with smaller scales. These smaller-scale features are represented in the detailed profiles measured by the FPS-16 radar/Jimsphere system (see Section 5.2.2.2).

A number of attempts have been made to represent the high frequency content of vertical wind profiles (gust) in a suitable form for use in vehicle design studies. Most of the attempts resulted in gust information which could be used for specific applications, but to date no universal gust representation has been formulated. Although discrete gusts are still widely used by various design organizations, the use of continuous gust representations in vehicle design studies is being intensively investigated. Information on discrete and continuous gusts is given below.

5.2.7.3.1 Discrete.

Discrete gusts are specified in an attempt to represent, in a physically reasonable manner, characteristics of small scale motions associated

* A detail analysis of the relative variations of shear, altitude, wind speed, and location is currently underway.

TABLE 5.15 IDEALIZED 99 PERCENTILE WIND SHEAR ENVELOPES FOR VARIOUS SCALES-OF-DISTANCE CORRESPONDING TO WIND SPEEDS IN THE ONE TO EIGHTY KM ALTITUDE REGION FOR ALL LOCATIONS

Wind Speed in the 1 to 80 km Altitude Region	Scale-of-Dista[illegible] (m)									
(ms^{-1})	5000	4000	3000	2000	1000	800	600	400	200	100
≥ 70	.0123	.0148	.0184	.0240	.0353	.0396	.0457	.0550	.0700	.0900
60	.0100	.0120	.0150	.0194	.0280	.0310	.0355	.0425	.0610	.0900
50	.0082	.0098	.0127	.0163	.0239	.0268	.0308	.0375	.0550	.0900
40	.0066	.0080	.0103	.0135	.0207	.0234	.0275	.0342	.0530	.0900
30	.0052	.0063	.0081	.0108	.0170	.0195	.0230	.0300	.0495	.0900
20	.0038	.0046	.0061	.0085	.0140	.0165	.0200	.0272	.0475	.0900
For Higher Wind Speeds in the 50 to 80 km Altitude Region	Scale-of-Distance (m)									
(ms^{-1})	5000	4000	3000	2000	1000	800	600	400	200	100
≥ 100	.0160	.0190	.0234	.0130	.0450	.0489	.0540	.0610	.0750	.0900

Graphical presentation of this table is shown in Figure 5.20

TABLE 5.16 IDEALIZED ENVELOPES OF 99 PERCENTILE WIND SPEED CHANGE FOR VARIOUS SCALES-OF-DISTANCE CORRESPONDING SPEEDS IN THE ONE TO EIGHTY KM ALTITUDE ALTITUDE REGION FOR ALL LOCATIONS

Wind Speed in the 1 to 80 km Altitude Region	Scale-of-Distance									
(ms^{-1})	5000	4000	3000	2000	1000	800	600	400	200	100
≥ 70	61.5	59.2	55.2	48.0	35.2	31.7	27.4	22.0	14.0	9.0
60	50.0	48.1	45.0	38.7	28.0	24.8	21.3	17.0	12.2	9.0
50	41.0	39.4	38.0	32.7	23.9	21.4	18.5	15.0	11.0	9.0
40	33.0	32.0	31.0	27.0	20.7	18.7	16.5	13.7	10.6	9.0
30	26.0	25.2	24.2	21.7	17.0	15.6	13.9	12.0	9.9	9.0
20	19.0	18.6	18.3	17.0	14.0	13.2	12.0	10.9	9.5	9.0
For Higher Wind Speeds in the 50 to 80 km Altitude Region	Scale-of-Distance									
(ms^{-1})	5000	4000	3000	2000	1000	800	600	400	200	100
≥ 100	80.0	76.0	70.3	62.0	45.0	39.1	32.4	24.4	15.0	9.0

Graphical Presentation of this table is shown in Figure 5.21

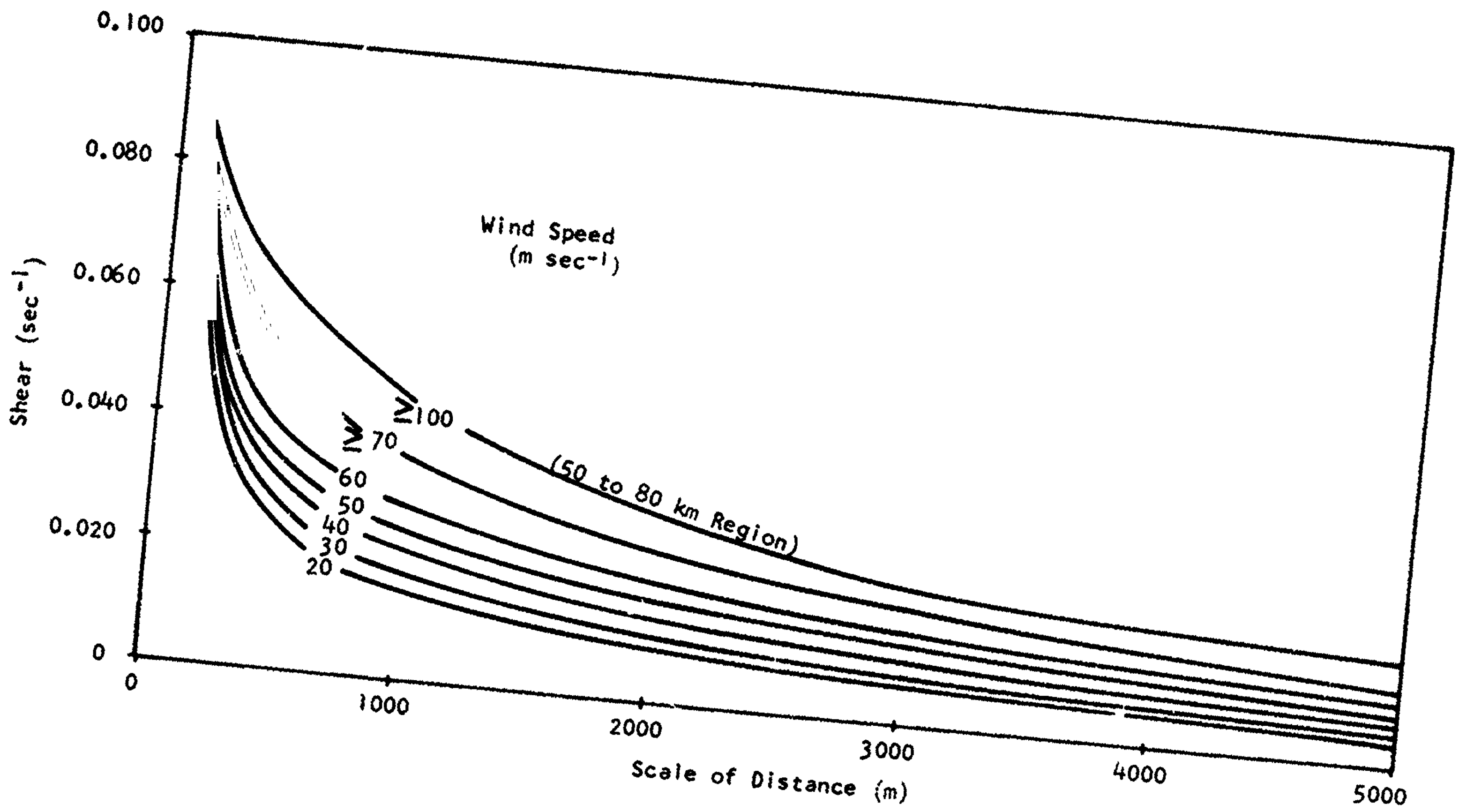

FIGURE 5.20 IDEALIZED 99 PERCENTILE WIND SHEAR (sec^{-1}) ENVELOPES FOR VARIOUS SCALES-OF-DISTANCE CORRESPONDING TO WIND SPEEDS IN THE ONE TO EIGHTY KM ALTITUDE REGION FOR ALL LOCATIONS

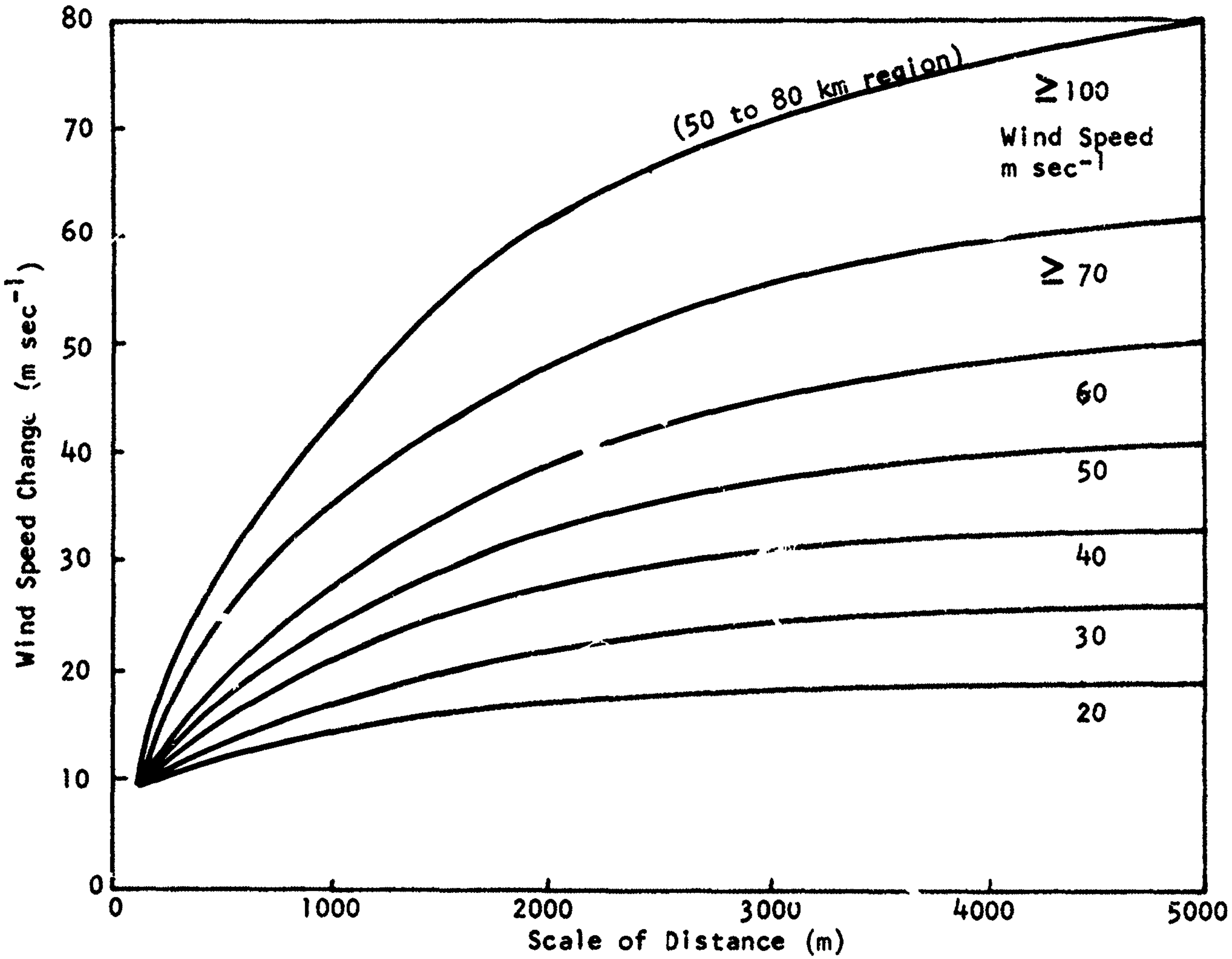

FIGURE 5.21 ENVELOPES OF 99 PERCENTILE WIND SPEED CHANGE (m sec^{-1}) FOR VARIOUS SCALES-OF-DISTANCE CORRESPONDING TO WIND SPEEDS IN THE ONE TO EIGHTY KM ALTITUDE REGION FOR ALL LOCATIONS

with vertical wind velocity profiles. Gust structure usually is quite complex and not well understood. For use in vehicle design studies, discrete gusts are usually idealized because of their complexity and to enhance their utilization.

Well defined, sharp-edged, and repeated sinusoidal gusts are important types in terms of their influence on space vehicles. Quasi-square-wave gusts with amplitudes of approximately 9 meters per second have been measured. These gusts are frequently referred to as embedded jets or singularities in the vertical wind profile. A gust is by definition a wind speed in excess of the defined quasi-steady-state value; therefore, these gusts are employed on top of the quasi-steady-state wind profiles.

Figure 5.22 shows a schematic representation of the quasi-square-wave gust with wavelengths varying between 50 and 300 meters with an amplitude of 9 meters per second. The shear buildup rate at the leading and trailing edges of the gust is 9 meters per second per 25 meters. The relationship of the gust to the idealized wind speed envelope and the wind buildup envelope is shown in the figure.

Another form of discrete gusts which has been observed is approximately sinusoidal in nature where gusts occur in succession. Figure 5.23 shows the number of consecutive sinusoidal gusts which may occur and their respective amplitudes. It is extremely important when applying these gusts in vehicle studies to realize these are pure sinusoidal representations which have never been observed to occur in nature. The degree of purity of these sinusoidal features on the vertical wind profiles has not been established. These gusts should be superimposed symmetrically on the quasi-steady-state profile. The data presented here on sinusoidal discrete gusts is at best preliminary and should be treated as such.

5.2.7.3.2 Continuous.

In general the small-scale motions associated with vertical detailed wind profiles are characterized by a superposition of discrete gusts and many random frequency components. Spectral methods have been employed to specify the characteristics of this superposition of small-scale motions.

A digital filter was developed to separate small scale motions from the quasi-steady-state wind profile. The quasi-steady-state wind profile defined by the separation process approximates those obtained by the rawinsonde system.* Thus a spectrum of small scale motions is representative of the motions included in the FPS-16 radar/Jimsphere measurements which are not included in the

* This definition was selected to enable use of the much larger rawinsonde data sample in association with a continuous type gust representation.

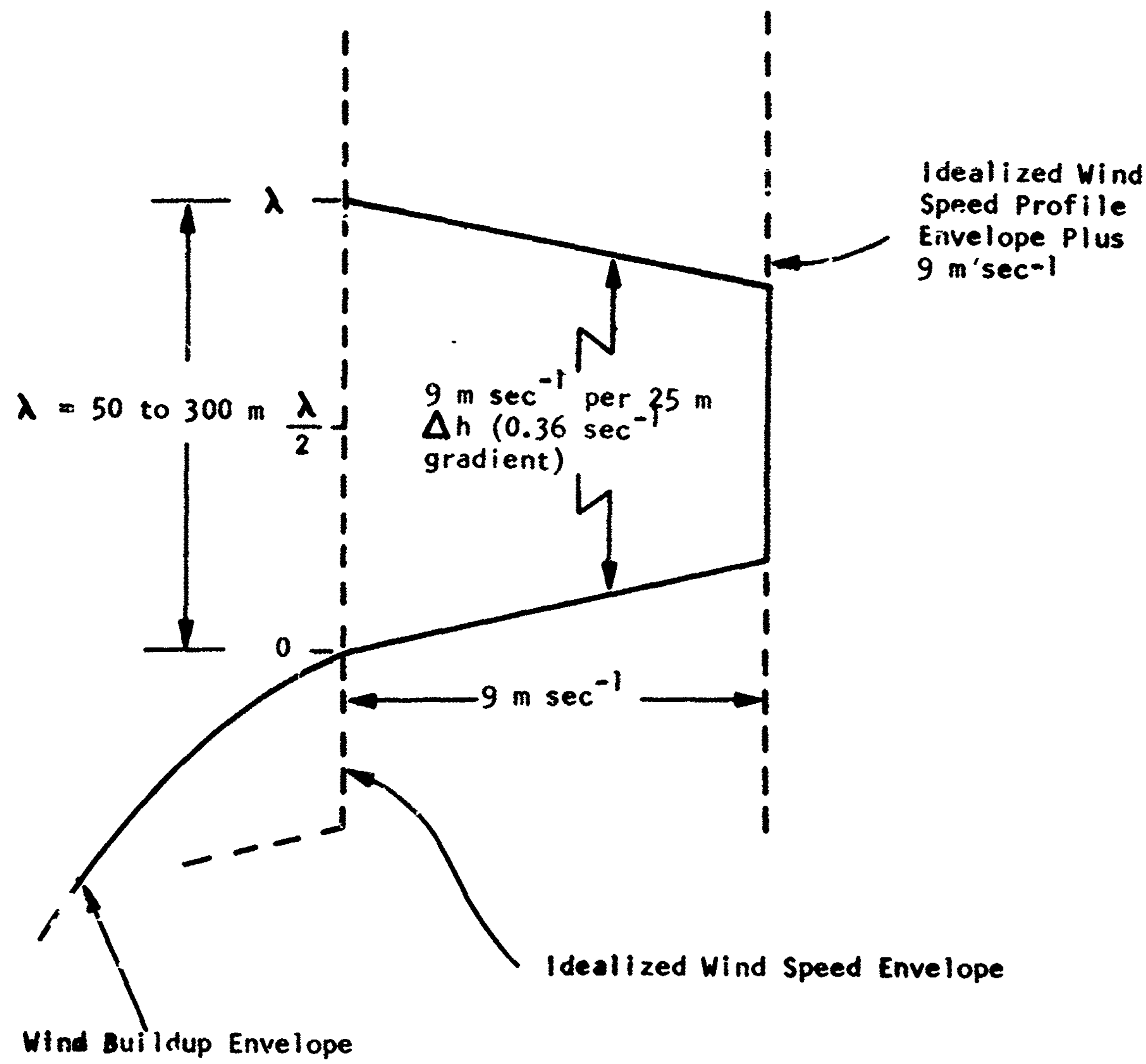

FIGURE 5.22 RELATIONSHIP BETWEEN ESTABLISHED GUSTS AND/OR EMBEDDED JET CHARACTERISTICS (QUASI-SQUARE WAVE SHAPE) AND THE IDEALIZED WIND SPEED (QUASI-STEADY-STATE) PROFILE ENVELOPE

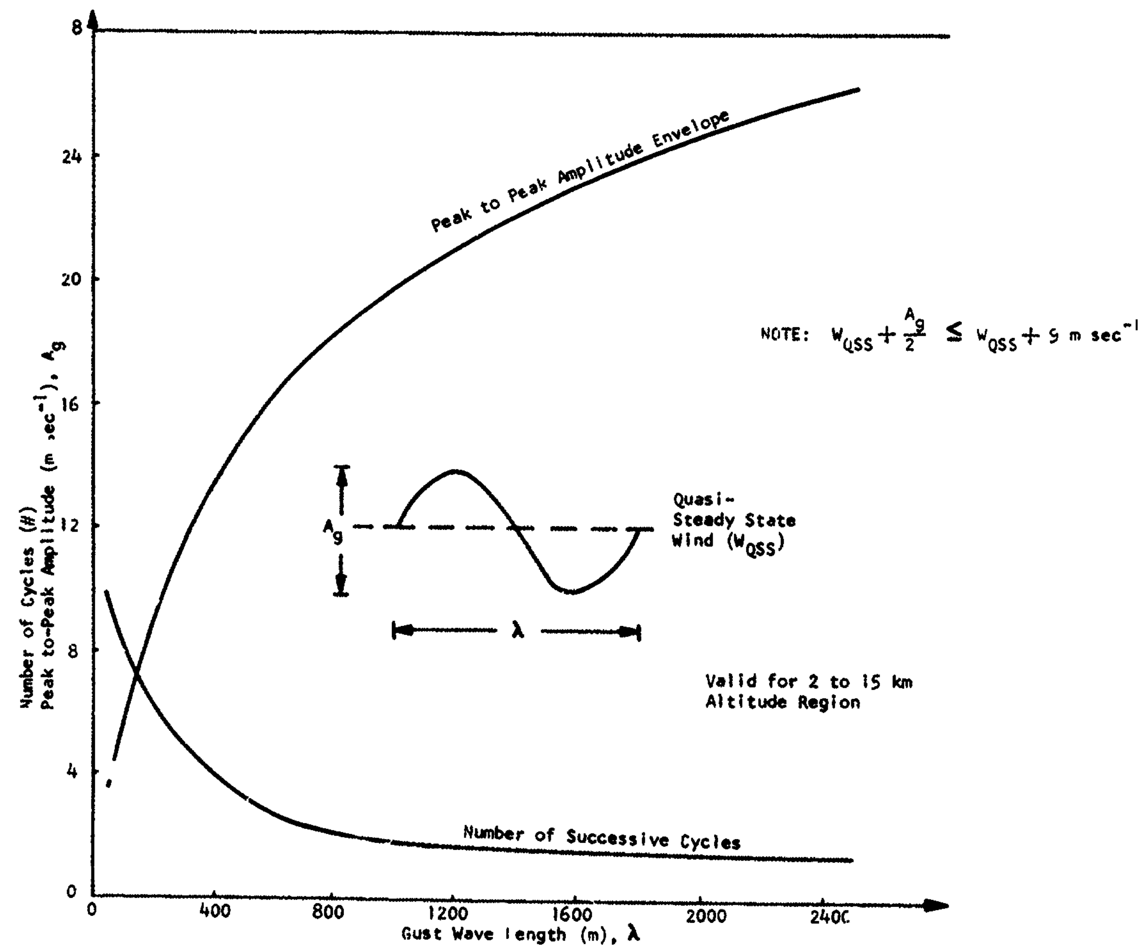

FIGURE 5.23. BEST ESTIMATE OF EXPECTED (≥99 PERCENTILE) GUST AMPLITUDE AND NUMBER OF CYCLES AS A FUNCTION OF GUST WAVELENGTH

rawinsonde measurements. Therefore, a spectrum of these motions should be added to the quasi-steady-state wind profiles to obtain a representation of the detailed wind profile. Spectra of the small scale motions associated with zonal, meridional, and scalar wind profiles for various probability levels have been determined and are presented in Figures 5.24A through 5.24C. The spectra were computed from approximately 200 detailed wind profile measurements by computing the spectra associated with each profile, then determining the probabilities of spectral density as a function of frequency. Thus the spectra represent envelopes of spectral density for the given probability levels. Spectra associated with each profile were computed over the entire altitude range of data, usually between approximately 2 and 16 kilometers. It has been shown that energy (variance) of the small scale motions is not homogeneous; i.e., it is not constant with altitude. The energy content over limited altitude intervals and for limited frequency bands may be much larger than that represented by the spectra in Figure 5.24. This should be kept in mind when interpreting the significance of vehicle responses when employing the spectra of small scale motions.

Also shown in Figure 5.24 are envelopes of spectra for detailed profiles without filtering. These spectra are well represented over wave numbers of 20 cy/4000 meters and less by an equation of the form

$$E = E_0 \; k^{-s}$$

where E_0 is the spectral density of the fundamental wave number, E the spectral density at any wave number k between 1 and 20, and s is the slope of the line. Properties of all the spectra are summarized in Table 5.17. Data presented in the table show that the small scale motions associated with the meridional profiles (generally cross wind component and in yaw plane) contain more energy than those associated with either the zonal or scalar profiles by a factor of approximately 4/3.

Because of computational difficulties, the spectra do not extend to wavelengths longer than 4000 meters. Variances associated with the spectra are given in Table 5.16. Spectra of the total wind speed profiles may be useful in control systems and other slow response parametric studies for which the spectra of small-scale motions may not be adequate.

5.2.7.4 Construction of Synthetic Wind Profiles.

Synthetic wind profiles may be constructed from quasi-steady-state wind speed and wind shear or speed change envelopes, as follows. An

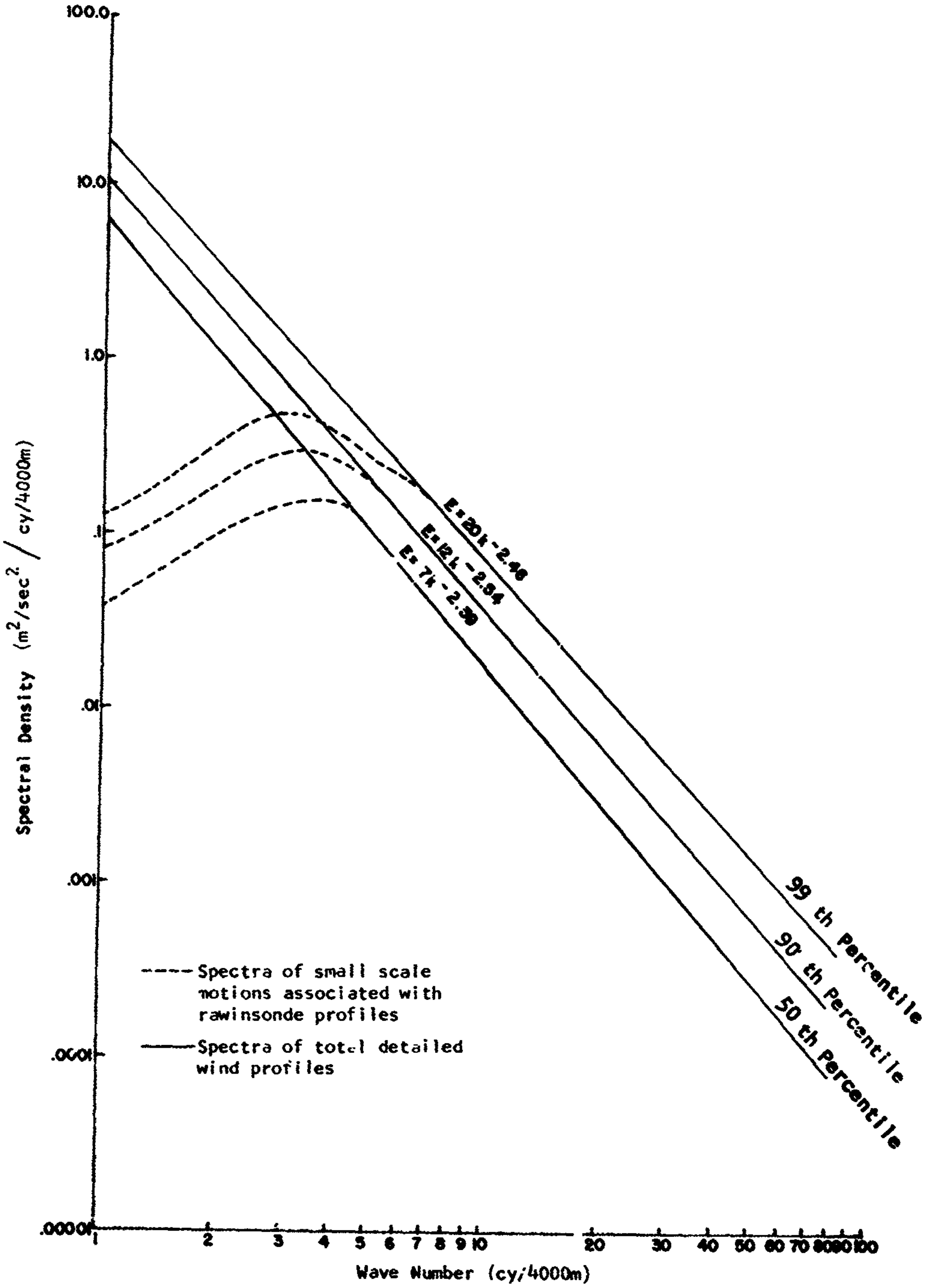

FIGURE 5.24A SPECTRA OF DETAILED WIND PROFILES - SCALAR

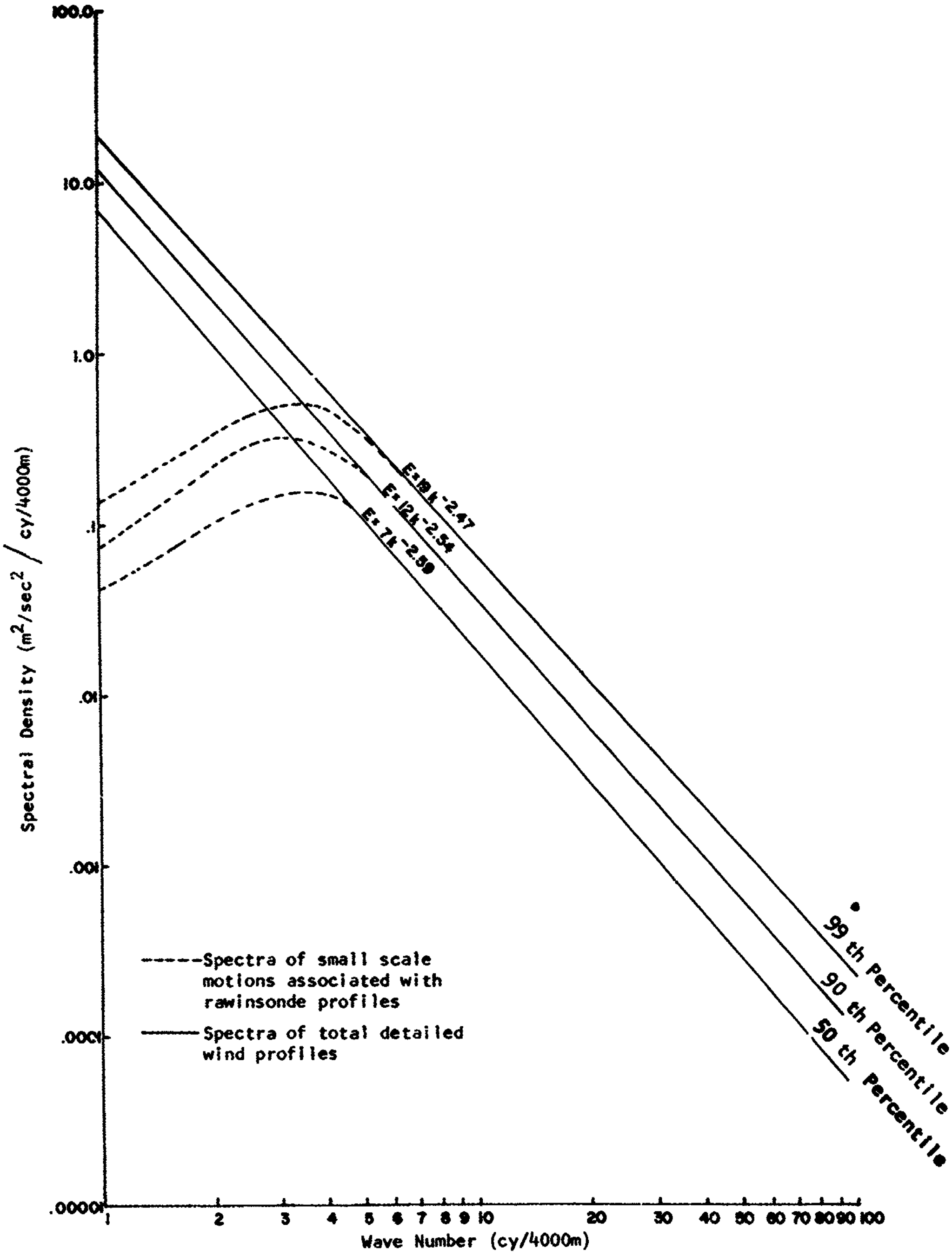

FIGURE 5.24B SPECTRA OF DETAILED WIND PROFILES - ZONAL

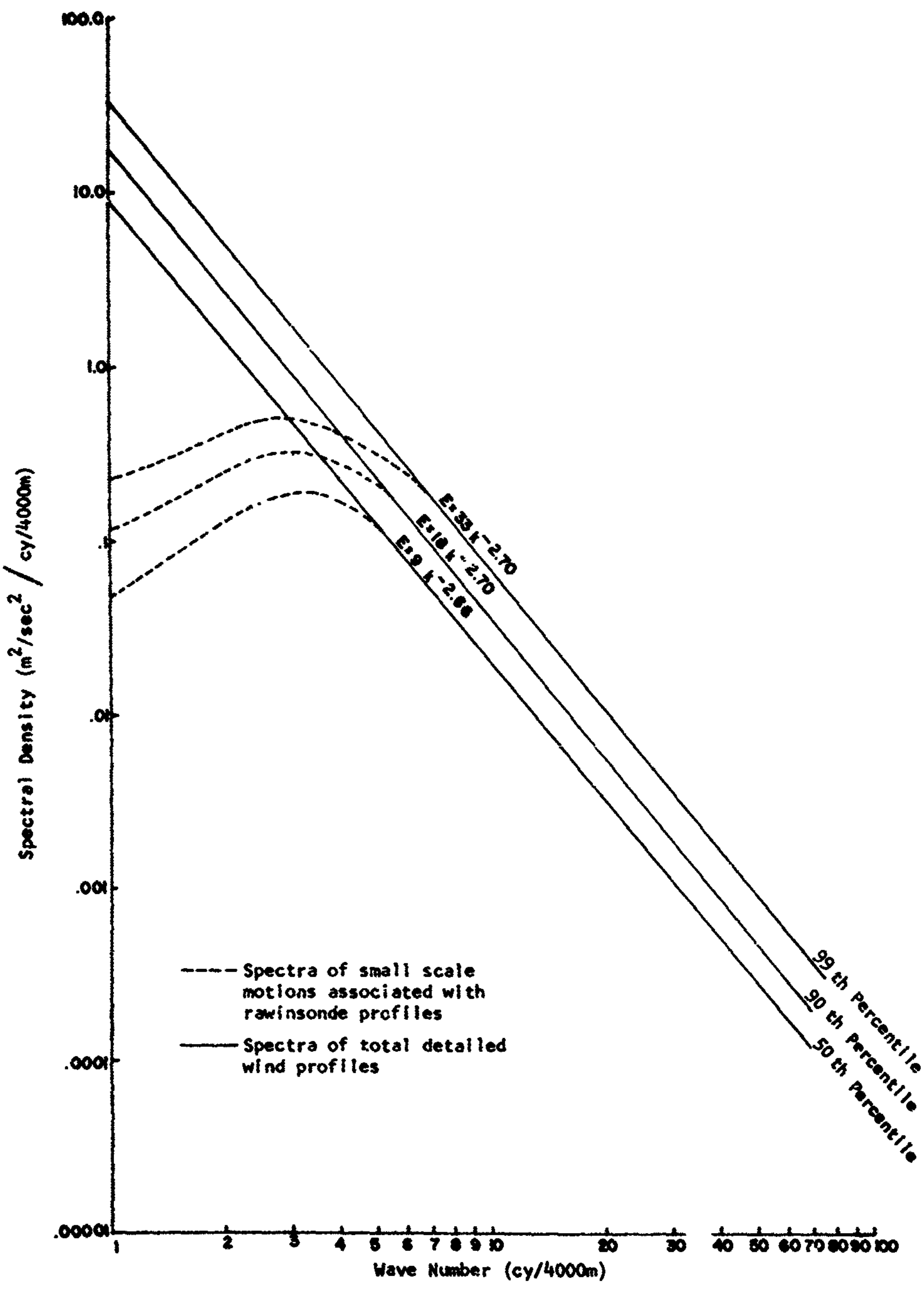

FIGURE 5.24C SPECTRA OF DETAILED WIND PROFILES - MERIDIONAL

TABLE 5.17 PARAMETERS DEFINING SPECTRA OF DETAILED WIND PROFILES

Percentile	W_x (Zonal)				W_z (Meridional)				V (Scalar)			
	E_0*	S_0*	$(Var)_T^*$	$(Var)_s$	E_0	S_0	$(Var)_T$	$(Var)_s$	E_0	S_0	$(Var)_T$	$(VAR)_s$
50	7	2.59	8.16	0.85	9	2.66	9.45	0.96	7	2.59	7.58	0.86
90	12	2.54	15.57	1.63	18	2.70	21.34	1.78	12	2.54	15.72	1.70
99	19	2.47	26.30	2.68	33	2.70	40.71	2.96	20	2.46	25.04	2.75

* E_0 - $m^2 \ s^{-2}/cy\ 4000\ m^{-1}$, constants associated with total profiles only only

S_0 - non-dimensional constants

Var - variance (m^2s^{-2}) associated with spectra

T - refers to total profiles

s - (subscript) refers to small-scale motion profiles

example is shown in Figure 5.25. Beginning with the wind speed envelope value at a given (reference) altitude, subtract the wind speed changes over the respective altitude layers (scales-of-distance) from the wind speed envelope value at the reference height, then plot the points at the bottom of the shear layer measured from the reference altitude downward. A smooth line joining these points then represents the shear buildup rate leading into the quasi-steady-state wind speed envelope at the reference height. For continuity, a line is drawn from the origin to the lowest point on the wind buildup envelope. The gust is then superimposed on the profile as shown in Figure 5.22. This completes the construction.

5.2.7.5 Relationships Between Wind Speeds, Wind Shears, and Gusts.

Correlations between speeds, shears, and gusts are not taken into account in the construction of synthetic profiles as described above. This problem has been and is being studied, but definitive conclusions have not been formulated from which functional relationships can be taken into account in constructing synthetic profiles. Studies have shown that shears calculated over small altitude intervals ($\lesssim$1 km) and gusts are poorly correlated with quasi-steady-state wind

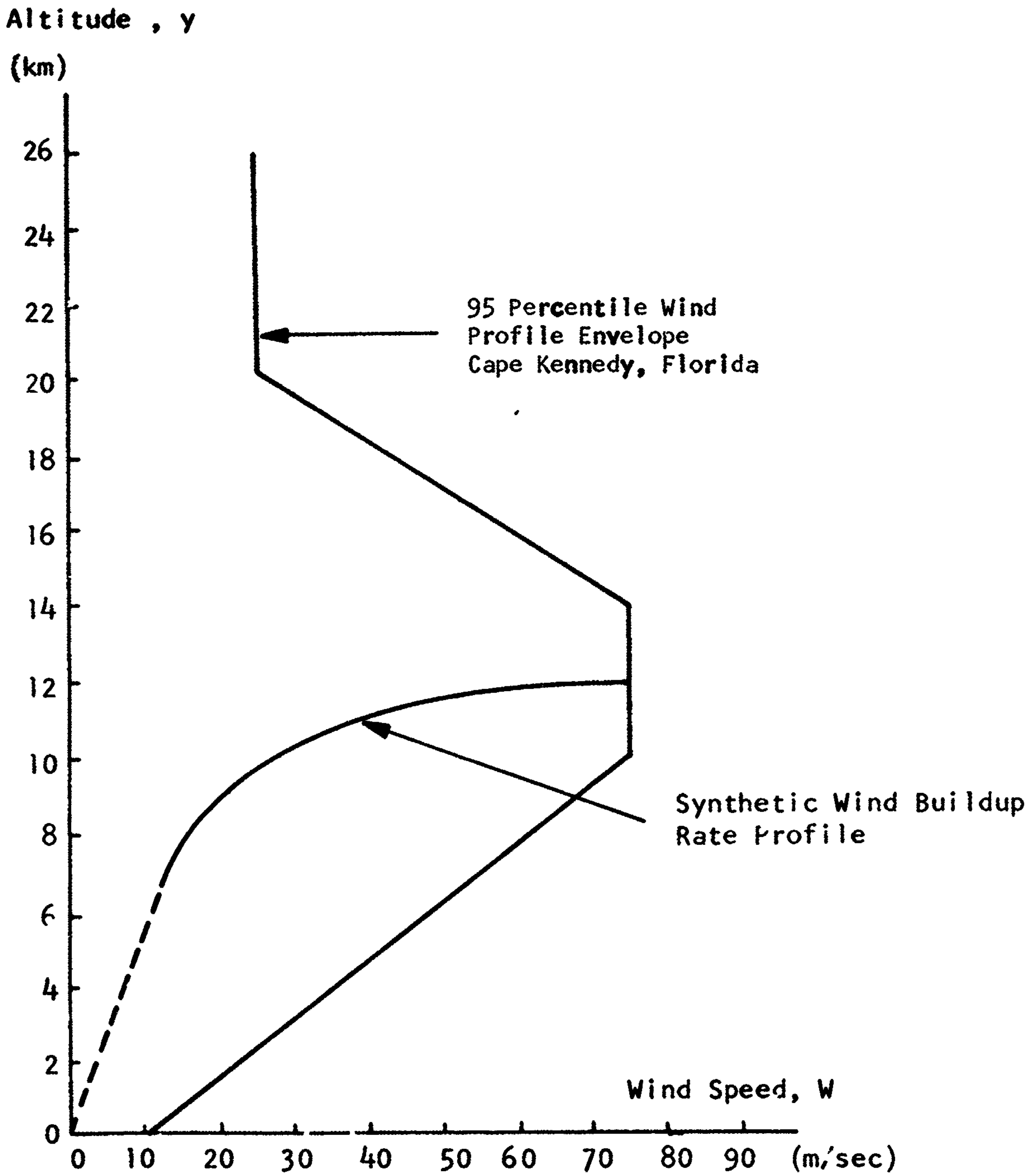

FIGURE 5.25 SYNTHETIC WIND PROFILE CONSTRUCTION BASED ON NINETY-NINE PERCENT WIND BUILDUP RATES ASSOCIATED WITH THE NINETY-FIVE PERCENTILE WIND SPEED PROFILE ENVELOPES AT THE 12 KM REFERENCE ALTITUDE

speeds, while shears over larger altitude intervals ($\gtrsim 1$ km) and quasi-steady-state wind speeds have a high positive correlation. Little is known about correlations between shears over various altitude intervals except that high probability-of-occurrence shears over more than two altitude intervals are poorly correlated. Even though functional relationships between wind speeds, shears, and gusts are not adequately known, reasonable approximations can be made in constructing synthetic profiles (see Section 5.2.7.1).

5.2.7.5.1 Method for Constructing Synthetic Wind Profiles Considering Relationships Between Shears, Speeds and Gusts.

The construction of synthetic profiles described in Section 5.2.7.4 above does not consider correlations (or lack of) between shears, speeds, and gusts. For synthetic profile construction, relationships between these parameters can be taken into account by considering shears and gusts to be independent of wind speeds (see Section 5.2.7.5). This is approximated by multiplying all shears and wind speed changes in Section 5.2.7.5 and the quasi-square-wave gust in Section 5.2.7.3 by a factor of 0.85 before constructing the synthetic profile. The gust may also be represented by a one-minus-cosine shape since line segments may tend to exaggerate vehicle responses (see below).

The following steps* may be taken to construct synthetic profiles considering relationships between shears, speeds, and gusts using the quasi-steady-state wind speed envelopes given in Section 5.2.4.1, the wind shears or wind speed changes given in Section 5.2.7.2, and the quasi-square-wave gust given in Section 5.2.7.3.1. This example employs the 95 percentile wind speed envelope, the 99 percentile wind shear envelope, and the quasi-square-wave gust.

a. The wind increases linearly, beginning at zero altitude and velocity, to a point where this line merges tangentially into the shear buildup envelope (multiplied by 0.85). (See Figure 5.26.)

b. Beginning at this point, it follows the 99 percent shear buildup envelope (multiplied by 0.85) to the 95 percent wind envelope. Construction of the shear buildup profile is unchanged, as described in Section 5.2.7.4.

c. The superimposed gust starts with an extension of the final slope of $(0.09)(0.85) = 0.0765 s^{-1}$ of the shear build-up envelope, to the point where it becomes tangent to the one-minus-cosine shape gust. (See Figure 5.27.)

(1) The gust consists of the linear extension of the shear build-up envelope, the buildup to the peak gust speed which is a one-minus-cosine

* This procedure is based on MSFC office memorandum R-AERO-Y-66-65 "Redefinition of the Saturn IB/V Synthetic Wind Profile," dated Sept. 10, 1965.

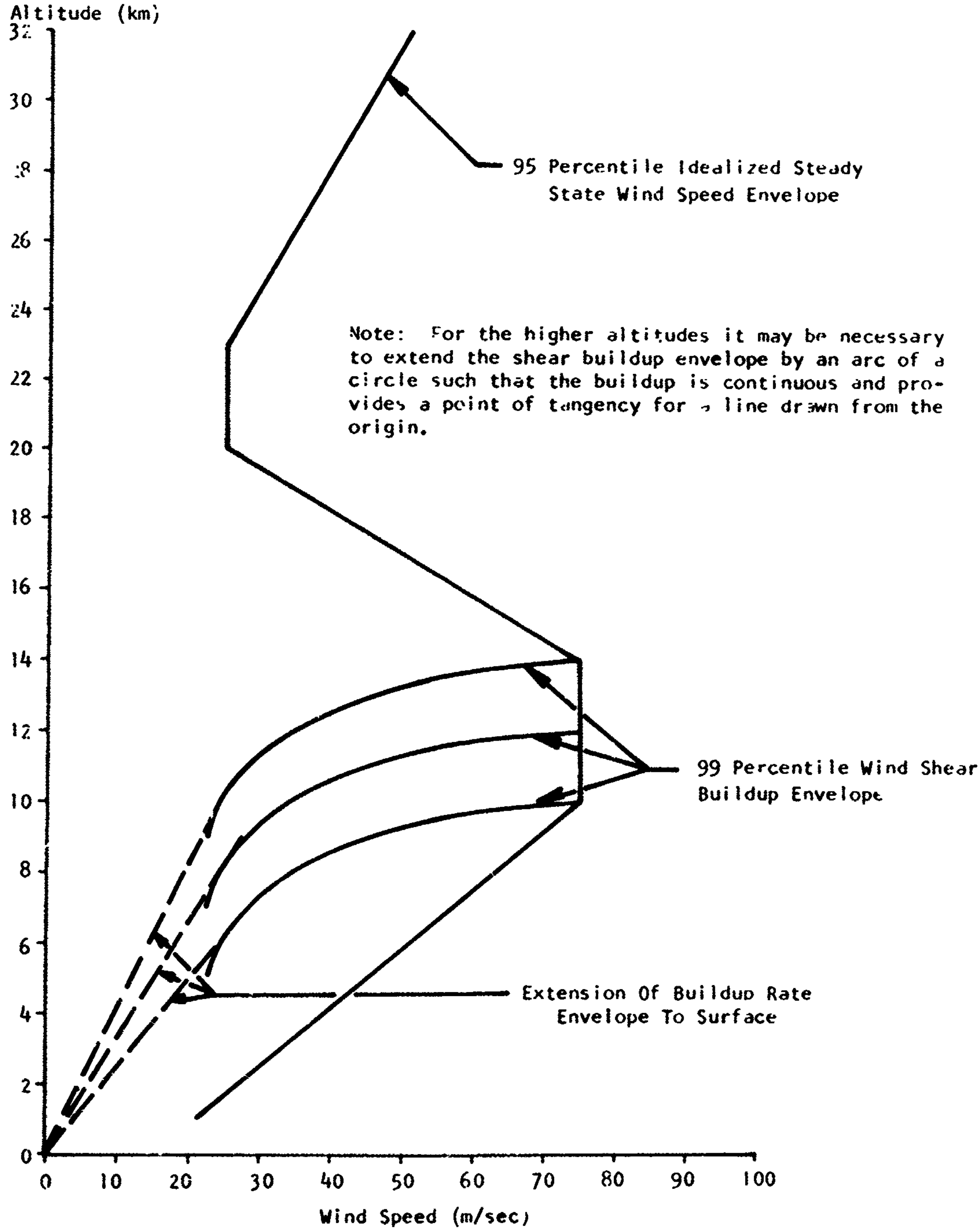

FIGURE 5.26 EXAMPLE OF THREE (10 km, 12 km, 14 km Altitude) SYNTHETIC WIND BUILDUP PROFILE CONSTRUCTIONS AND EXTENSION TO SURFACE AS APPLIED TO 95 PERCENTILE IDEALIZED STEADY STATE WIND SPEED ENVELOPE

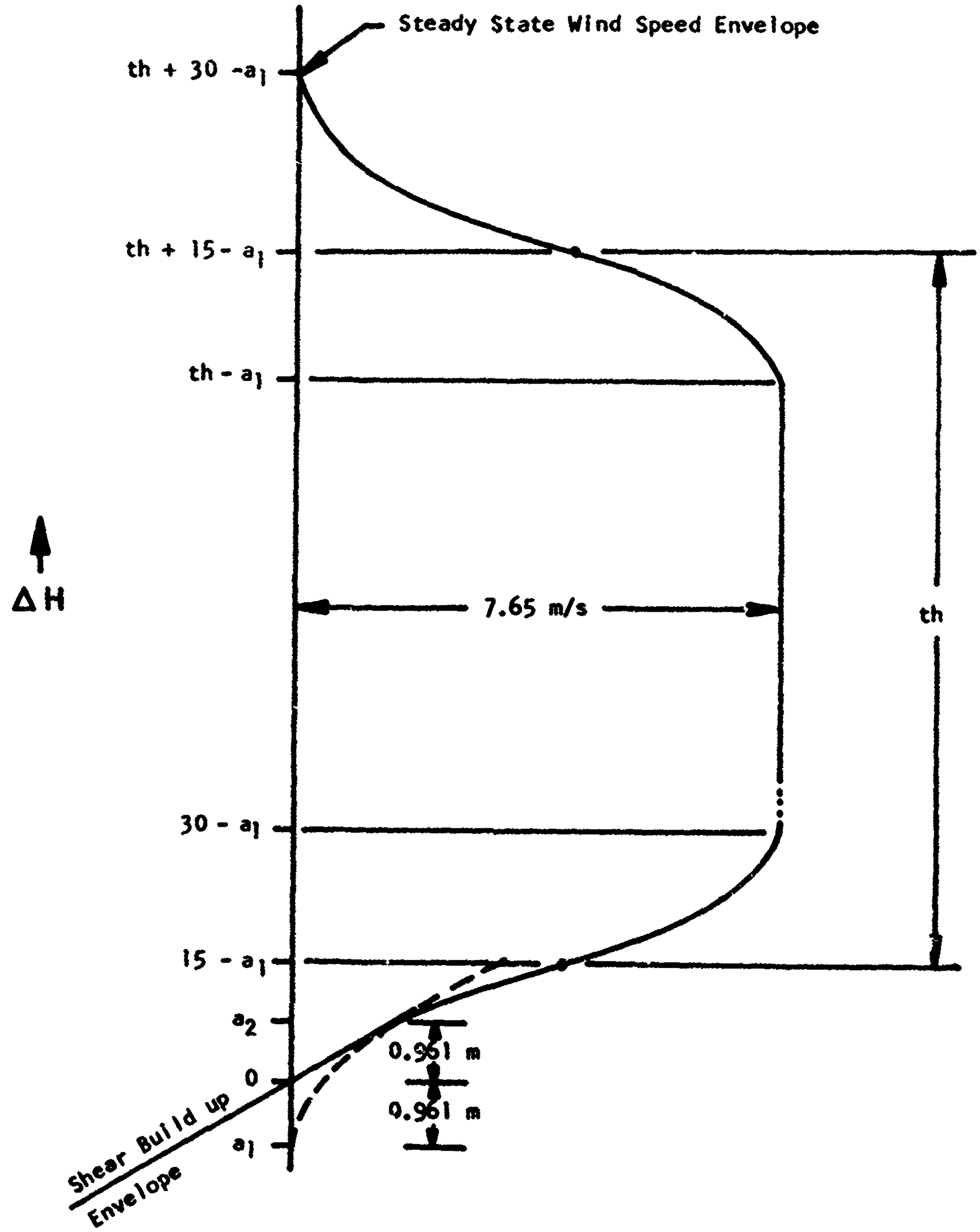

FIGURE 5.27 RELATIONSHIP BETWEEN REVISED GUST SHAPE (EMBEDDED JET), STEADY STATE WIND SPEED ENVELOPE, AND WIND SHEAR BUILDUP ENVELOPE (REFER TO TEXT FOR DEFINITION OF SYMBOLS)

curve with a half wave length of thirty (30) meters (altitude) and a double amplitude (total wind speed increase) of $0.85 \times 9\ ms^{-1} = 7.65\ ms^{-1}$, the constant velocity plateau, and the tail-off which is the second half of the one-minus-cosine wave. The "thickness" of the gust will be defined by the altitude difference of the inflection points of the buildup and the tail-off curves. (See Figure 5.27.)

(2) Referring to the point where the <u>shear</u> build-up envelope intersects the steady-state envelope, the gust is described (Figure 5.27) by the following equations:

<u>a</u> $0 \le \Delta H \le a_2$ $\qquad \Delta W_G = (0.09)(0.85)\Delta H = 0.0765\Delta H$

<u>b</u> $a_2 \le \Delta H \le 30 - a_1$ $\qquad \Delta W_G = 3.825\{1 - \cos[\frac{\pi}{30}(\Delta H + a_1)]\}$

<u>c</u> $30 - a_1 \le \Delta H \le th - a_1$ $\qquad \Delta W_G = 7.65$

<u>d</u> $th - a_1 \le \Delta H \le th + 30 - a_1$ $\qquad \Delta W_G = 3.825\{1 - \cos[\frac{\pi}{30}(\Delta H + 30 + a_1 - th)]\}$

<u>e</u> $th + 30 - a_1 \le \Delta H$ $\qquad \Delta W_G = 0$

where

ΔH is altitude difference (m)

ΔW_G is gust wind speed (ms^{-1})

a_1 is the shift of the one-minus-cosine build-up required to a tangential change-over from the shear build-up envelope and the gust (m)

a_2 is the tangent point of the shear build-up envelope and the gust (m)

th is the "thickness" of the gust (m)

$a_1 = a_2 = 0.916$ m.

Obviously the "thinnest" gust that can be simulated equals the half-wave-length of the cosine so that

30 m ≤ gust thickness ≤ 275 m.

d. After the gust is reduced to zero at end of tail-off, the "Synthetic Wind Profile" follows the 95 percent wind speed envelope.

It is recognized that no single wind profile representation is applicable for all design problems. Therefore, confirmation is required on the validity of any given wind input for design applications. A more general description of the wind environment is being developed.

5.2.8 Availability of Detailed Wind Velocity Profiles

There are at present approximately 500 reduced and edited detailed wind velocity profiles available that were measured by the FPS-16 radar/Jimsphere method at the Eastern and Western Test Ranges. Some of these data have been published (Ref. 5.11). All the data are presently on magnetic tapes in the MSFC Computation Laboratory. A master tape has been prepared to make the data readily accessible to engineers for use in space vehicle design and operation studies. Reasonable quantities of these data can be made available to the aerospace community upon request to the Chief, Aerospace Environment Division, Aero-Astrodynamics Laboratory, NASA/MSFC, Huntsville, Alabama 35812.

5.2.9 Availability of Rawinsonde Wind Velocity Profiles

Serially complete, edited and corrected rawinsonde wind profile data are available for eight years, two observations a day for Cape Kennedy, Florida (Eastern Test Range) and for nine years, four observations a day for Santa Monica, California (Western Test Range Area). These data are presently on magnetic tapes in the Marshall Space Flight Center Computation Laboratory. Qualified requestors in aerospace, scientific, and engineering organizations may obtain these data upon request to Chief, Aerospace Environment Division, Aero-Astrodynamics Laboratory, Marshall Space Flight Center, NASA, Huntsville, Alabama 35812.

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SECTION VI. ABRASION

By

Glenn E. Daniels

6.1 Introduction.

Particles carried by wind will remove paint from exposed surfaces or scratch, abrade, or erode them, and pit transparent surfaces. When the wind velocities are low or moderate, damage can occur whenever the particle hardness is equal to or greater than the exposed surface. When the relative speed of an object with relation to atmospheric particles is high, erosion will occur even when the particles have a hardness less than the exposed surface. For example, raindrops may cause erosion if the relative velocities between the vehicle surface and raindrops are great enough (over 100 m sec^{-1} or 194 knots, Ref. 6.1).

The penetration of sand and dust into moving parts (bearings, gears, etc.) can result in abnormal wear and failure. Large sand and dust particles may be suspended in the atmosphere during periods of high winds and low humidities (under 50 percent). Particles of dust less than 0.002 mm (0.000078 in.) in diameter are common at any time near or over land surfaces except shortly after precipitation. Particles larger than 0.002 mm (0.000078 in.) will settle out rapidly unless wind or other forces are present to keep the particles suspended. Small particles in the atmosphere over the sea will consist almost entirely of salt.

Particle hardness in this section is expressed according to Mohs' hardness scale, which is based on the relative hardness of representative minerals as listed in Table 6.1 (Ref. 6.2).

TABLE 6.1 MOHS' SCALE-OF-HARDNESS FOR MINERALS

Mohs' Relative Hardness	Mineral	Mohs' Relative Hardness	Mineral
1	Talc	6	Orthoclase
2	Gypsum	7	Quartz
3	Calcite	8	Topaz
4	Fluorite	9	Corundum
5	Apatite	10	Diamond

6.2 Sand and Dust at Surface.

The presence of sand and dust can be expected at all areas of interest, but will occur more frequently in the areas with lower water vapor concentration. The extreme values expected are as follows:

6.2.1 Size of Particles.

a. Sand particles will be between 0.080 mm (0.0031 in.) and 1.0 mm (0.039 in.) in diameter. At least 90 percent of the particles will be between 0.080 mm (0.0031 in.) and 0.30 mm (0.012 in.) in diameter.

b. Dust particles will be between 0.0001 mm (0.0000039 in.) and 0.080 mm (0.0031 in.) in diameter. At least 90 percent of these particles will be between 0.0001 mm (0.0000039 in.) and 0.002 mm (0.000079 in.) in diameter.

6.2.2 Hardness and Shape.

More than 50 percent of the sand and dust particles will be composed of angular quartz or harder material, with a hardness of 7 to 8.

6.2.3 Number and Distribution of Particles.

a. Sand. For a steady-state wind speed of 10 m sec^{-1} (19.4 knots) at 3 m (9.9 ft) above surface and relative humidity of 30 percent or less, there will be 0.02 g cm^{-3} (1.2 lb ft^{-3}) of sand suspended in the atmosphere during a sand storm. Under these conditions, 10 percent of the sand grains will be between 0.02 m (0.079 ft) and 1.0 m (3.3 ft) above the ground surface, with the remaining 90 percent below 0.02 m (0.079 ft), unless disturbed by a vehicle moving through the storm.

When the steady-state wind speed decreases below 10 m sec^{-1} (19.4 knots), the sand grains will be distributed over a smaller distance above the ground surface; while a steady-state wind speed below 5 m sec^{-1} (9.7 knots) will not be sufficient to set the grains of sand in motion.

As the steady-state wind speed increases above 10 m sec^{-1} (19.4 knots), the sand grains will be distributed over higher and higher distances above the ground surface.

b. Dust. For a steady-state wind speed of 10 m sec^{-1} (19.4 knots) at 3 m (9.9 ft) above surface, and relative humidity of 30 percent or less, there will be 6×10^{-9} g cm^{-3} (3.7×10^{-7} lb ft^{-3}) of dust suspended in the atmosphere. Distribution will be uniform to about 200 m (656 ft) above the ground.

6.3 Sand and Dust at Altitude.

Only small particles (less than 0.002 mm [0.000079 in.]) will be in the atmosphere above 400 m (1312 ft) in the areas of interest. During actual flight, the vehicle should pass through the region of maximum dust in such a short time that little or no abrasion can be expected.

6.4 Snow and Hail at Surface.

Snow and hail can cause abrasion at Huntsville, River Transportation, New Orleans, Wallops Test Range, and White Sands Missile Range areas. Extreme values expected with reference to abrasion are as follows:

6.4.1 Snow Particles.

Snow particles will have a hardness of 2 to 4 (Ref. 6.3) and a diameter of 1.0 mm (0.039 in.) to 5.0 mm (0.20 in.). Steady-state wind speed of 10 m sec^{-1} (19 knots) at a minimum air temperature of -17.8°C (0°F) should be considered for design calculations. At New Orleans a minimum air temperature of -9.4°C (15°F) should be used.

6.4.2 Hail Particles.

Hail particles will have a hardness of 2 to 4 and a diameter of 5.0 mm (0.20 in.) or greater. Steady-state wind speed of 10 m sec^{-1} (19 knots) at an air temperature of 10.0°C (50°F) should be considered for design calculations.

6.5 Snow and Hail at Altitude.

Snow and hail particles will have higher hardness values at higher altitudes. The approximate hardness of snow and hail particles in reference to temperature is given in Table 6.2 (See paragraph 4.4.2 remarks).

TABLE 6.2 HARDNESS OF HAIL AND SNOW FOR ALL LOCATIONS

Temperature		Relative Hardness (Mohs' Scale)
(°C)	(°F)	
0	32.0	2
-20	- 4.0	3
-40	-40.0	4
-60	-76.0	5
-80	-112.0	6

Although the flight time of a vehicle through a cloud layer will be extremely short, if the cloud layer contains a large concentration of moderate sized hailstones (25 mm [1 in.] or larger) at temperatures below - 20.0°C (-4°F), considerable damage could be expected (especially to antennas and other protrusions) because of the kinetic energy of the hailstone at impact. Tests have shown a definite relationship between the damage to aluminum aircraft wing sections and the velocity of various sized hailstones. Equal dents (sufficient to require repair) of 1 mm (0.039 in.) in 75 S-T aluminum resulted from the following impacts (Ref. 6.4):

a. A 19-mm (0.75 in.) ice sphere at 190 m sec^{-1} (369 knots).

b. A 32-mm (1.25 in.) ice sphere at 130 m sec^{-1} (253 knots).

c. A 48-mm (1.88 in.) ice sphere at 90 m sec^{-1} (175 knots).

6.6 Raindrops.

With the advent of high-speed aircraft a new phenomenon has been encountered in the erosion of paint coatings, of structural plastic components, and even of metallic parts by the impingement of raindrops on surfaces. The damage may be severe enough to affect the performance of a space vehicle. Tests conducted by the British Ministry of Aviation (Ref. 6.1) have resulted in a table of rates of erosion for various materials and coatings. These materials and coatings were tested at speeds of 220 m sec^{-1} (428 knots). Sufficient data are not available to present any specific extreme values for use in design, but results of the tests indicate that materials used should be carefully considered and weather conditions evaluated prior to launch.

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SECTION VII. ATMOSPHERIC PRESSURE

7.1 Definition.

Atmospheric pressure (also called barometric pressure) is the force exerted as a consequence of gravitational attraction, by the mass of the column of air of unit cross section lying directly above the area in question. It is expressed as a force per unit area.

7.2 Pressure at Surface.

The total variation of pressure from day to day is relatively small. Rapid but slightly greater variations occur as the result of the passage of frontal systems, while the passage of a hurricane can cause somewhat larger, but still not significant changes for pressure environment design of space vehicles. Surface pressure extremes for various locations and their extreme ranges are given in Table 7.1. Revisions have been made to these data from the data given in TM X-53023 (Ref. 7.1) by use of the results of a study of pressure extremes (Ref. 7.2 and Section XV).

7.3 Pressure Change.

a. A gradual rise or fall in pressure of 3 mb (0.04 lb in.$^{-2}$) and then a return to original pressure can be expected over a 24-hour period.

b. A maximum pressure change (frontal passage change) of 6 mb (0.09 lb in.$^{-2}$) (rise or fall) can be expected within a 1-hour period at all localities.

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TABLE 7.1 SURFACE PRESSURE EXTREMES

Area	Pressure				Elevation (from mean sea level) of Equivalent Station with Standard Atmospheric Conditions			
	Units	Maximum	Mean	Minimum	Units	Maximum	Mean	Minimum
Huntsville	newton m^{-2}	102500	98800	96000	m	- 92	202	432
	mb	1025	988	960				
	lb $in.^{-2}$	14.9	14.9	13.9	ft	- 302	663	1417
River Transportation	newton m^{-2}	104400	100000	95000*	m	-238	106	516
	mb	1044	1000	950*				
	lb $in.^{-2}$	15.1	14.5	13.8*	ft	-781	348	1693
New Orleans, Gulf Transportation, Panama Canal Transportation, and Wallops Test Range	newton m^{-2}	105000	101325	90000*	m	-285	0	948
	mb	1050	1013.25	900*				
	lb $in.^{-2}$	15.2	14.7	13.1*	ft	-935	0	3110
Eastern Test Range	newton m^{-2}	103550	101750	99250	m	-185	-40	166
	mb	1035.5	1017.5	992.5				
	lb $in.^{-2}$	15.0	14.8	14.4	ft	-606	-133	544
West Coast Transportation, Western Test Range, and Sacramento	newton m^{-2}	104800	101325	93800	m	-265	0	617
	mb	1048	1013.25	938				
	lb $in.^{-2}$	15.2	14.7	13.6	ft	-882	0	2024
White Sands Missile Range	newton m^{-2}	90700	88000	82800	m	886	1216	1614
	mb	907	880	828				
	lb $in.^{-2}$	13.2	12.8	12.0	ft	2907	3989	5295

* During hurricane conditions

SECTION VIII. ATMOSPHERIC DENSITY

8.1 Definition.

Density is the ratio of the mass of a substance to its volume. (It also is defined as the reciprocal of specific volume.) Density is usually expressed in grams or kilograms per cubic centimeter or cubic meter.

8.2 Atmospheric Density at Surface.

The variation of the density of the atmosphere at the surface from the average for any one station, and between the areas of interest, is small and should have no important effect on preflight operations. Table 8.1 gives the median density at the surface for the four test ranges.

Table 8.1 Median Surface* Densities

Area	Surface Altitude	Source of Data	Density	
	m		kg m^{-3}	lb ft^{-3}
Eastern Test Range	5	(Ref. 8.1)	1.1835	7.388×10^{-2}
Western Test Range	61	(Ref. 8.2)	1.2267	7.658×10^{-2}
White Sands Missile Range	1219	(Ref. 8.3)	1.049	6.549×10^{-2}
Wallops Test Range	2	(Ref. 8.4)	1.2320	7.691×10^{-2}

8.3 Data on density distribution with altitude are given in Section XIV.

* At station elevation above mean sea level.

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SECTION IX. ATMOSPHERIC ELECTRICITY

By

Glenn E. Daniels

9.1 Thunderstorm Electricity.

Space vehicles not adequately protected can be damaged by (1) direct lightning stroke, (2) current induced in the vehicle from a nearby object struck by lightning, (3) charge induced by nearby charged clouds, or (4) a large buildup of the atmospheric potential gradient. Protection of the vehicle is accomplished in several ways by (1) ensuring that all metallic sections are connected electrically (bonded) so that the current flow from a lightning stroke is conducted over the skin without any gaps where sparking would occur or current would be carried inside. MIL-B-5087 A(ASG), 30 July 1954, and later amendments (Ref. 9.1) give requirements for electrical bonding; (2) objects on the ground, such as buildings, may be protected by a system of lightning rods and wires over the outside to carry the lightning stroke to the ground; or (3) by a cone of protection as shown in Reference 9.2 for the lightning protection plan for Saturn Launch Complex 39.

If lightning should strike a space vehicle ready for test or flight, or a large metallic object nearby such as the test stand or gantry, a complete checkout will be required of all electronic components and moving parts in the vehicle. Potential gradient recorders which will give warning of dangerous conditions in the local area are currently being produced commercially. If potential gradient is a critical item, the use of a unit to monitor potential gradient conditions during test periods should be considered.

9.1.1 Frequency of Occurrence of Thunderstorms.

The frequency of occurrence of "thunderstorm days" (number of days per year on which thunder is heard) is an approximate guide to the probability of lightning strokes to earth in a given area. The number of thunderstorm days per year is called the "isokeraunic level." A direct lightning strike is possible at all locations of interest, but the frequency of such an occurrence varies between the locations, as given in Table 9.1 (Refs. 9.2 and 9.3).

TABLE 9.1 FREQUENCY-OF-OCCURRENCE OF "THUNDERSTORM DAYS" (ISOKERAUNIC LEVEL)

Location	Mean Number of Days Per Year for Thunderstorms		Monthly Distribution (percent of annual)											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Huntsville	70	%	1	3	6	8	11	19	22	18	9	1	1	1
		No. Days	0.70	2.10	4.20	5.60	7.70	13.30	15.40	12.60	6.30	0.70	0.70	0.70
River Transportation and New Orleans	75	%	3	3	5	5	8	16	21	20	10	3	3	3
		No. Days	2.25	2.25	3.75	3.75	6.0	12.0	15.75	15.0	7.5	2.25	2.25	2.25
Gulf Transportation	90	%	1	1	4	2	9	18	24	23	12	4	1	1
		No. Days	0.90	0.90	3.60	1.80	8.10	16.20	21.60	20.70	10.80	3.60	0.90	0.90
Eastern Test Range	75	%	1	2	5	5	9	19	18	20	14	5	1	1
		No. Days	0.75	1.50	3.75	3.75	6.75	14.25	13.50	15.00	10.50	3.75	0.75	0.75
Panama Canal Transportation	100	%	1	1	4	2	9	18	24	23	12	4	1	1
		No. Days	1.0	1.0	4.0	2.0	9.0	18.0	24.0	23.0	12.0	4.0	1.0	1.0
Western Test Range and West Coast Transportation	6	%	9	11	19	13	7	4	3	7	8	8	3	8
		No. Days	0.54	0.66	1.14	0.78	0.42	0.24	0.18	0.42	0.48	0.48	0.24	0.48
Sacramento	4	%	6	16	12	15	9	6	3	3	10	12	5	3
		No. Days	0.24	0.64	0.48	0.60	0.54	0.24	0.12	0.12	0.40	0.48	0.20	0.12
Wallops Test Range	41	%	1	2	5	7	13	19	24	18	7	2	1	1
		No. Days	0.41	0.82	2.05	2.87	5.33	7.79	9.84	7.38	2.87	0.82	0.41	0.41
White Sands Missile Range	35	%	1	1	3	6	14	19	24	18	9	3	1	1
		No. Days	0.35	0.35	1.05	2.10	4.90	6.65	8.40	6.30	3.15	1.05	0.35	0.35

9.1.2 Frequency of Lightning Strokes to Earth.

If the isokeraunic level is multiplied by 0.23 (Ref. 9.2), a good estimate can be obtained of the stroke frequency to the earth per square mile. For the 0.2 square mile launch area of Saturn Launch Complex 39, this gives four strokes per year or nearly one stroke for the month of August. The probable number of strokes per year to buildings of different heights will increase with height as shown in Table 9.2.

TABLE 9.2 ESTIMATE OF THE NUMBER OF LIGHTNING STROKES PER YEAR FOR VARIOUS HEIGHTS (EASTERN TEST RANGE) (Ref. 9.2)

Height (m)	Height (feet)	Number of Lightning Strokes (per year)
30.5	100	0.4
61.0	200	1.1
91.4	300	2.3
121.9	400	3.5
152.4	500	4.4
182.9	600	5.3
213.4	700	5.8

9.1.3 Characteristics of Lightning Strokes.

Lightning strokes have the following characteristics at all the areas covered by this document (Refs. 9.4, 9.5 and 9.6):

a. An average peak current of 10,000 amperes can be expected. The peak current flow is reached 6 microseconds after start of stroke, with a fall to one-half the peak value in 24 microseconds. A total stroke charge of 25 coulombs is transmitted to the earth with 90 percent of the current flow, after the initiation of the first stroke, at less than 1000 amperes.

b. The maximum peak current will not be greater than 100,000 amperes 90 percent of the time. This peak current flow is reached in 10 microseconds after start of the stroke, and the current then falls to one-half the peak value in 20 microseconds. A total stroke charge of 100 coulombs is transmitted to the earth, with 95 percent of the current flow, after the initiation of the first stroke, at less than 5000 amperes.

9.1.4 Induced Charge from Atmospheric Potential Gradient.

In many cases, current may be induced in equipment from the atmospheric potential gradient. Normally on a clear day the potential gradient of the atmosphere at the earth's surface averages about 300 volts m^{-1}. Even this potential on a 100-meter-high vehicle could amount to a 30,000 volt potential between the ground and top, if the vehicle is not grounded. With the development of cumulus clouds the potential gradient will increase. If it reaches as high as 3×10^6 volts m^{-1} (the average breakdown voltage of air), then a lightning flash may occur.

Because of the potential gradient, on days when scattered clouds occur, severe shocks can result from the charge induced along a metal cable on a captive balloon. Similarly induced charges on home television antennas have exploded fine wire coils in television sets. Such equipment damage can be prevented by installing lightning arresters with air gaps small enough to discharge the current before it discharges within the equipment.

9.1.5 Radio Interference.

Whenever an electrical charge produces a spark between two points, electromagnetic radiation is emitted. This discharge is not limited to a narrow band of frequencies, but covers most of the electromagnetic radiation spectrum with various intensities. Most static heard in radio reception is related to electrical discharges, with lightning strokes contributing a large percentage of the interference. This interference from lightning strokes is propagated through the atmosphere in accordance with laws valid for ordinary radio transmission and may travel for great distances. With the transmission of interference from lightning strokes over great distances, certain frequencies remain prominent, with 30 kc being the major frequency. For this reason, the interference to telemetering and guidance needs be considered only when thunderstorms are occurring within 100 km (60 miles) of the space vehicle site. Prediction of such weather should be obtainable from the local weather forcast personnel.

9.1.6 Coronal Discharge.

As the atmospheric potential gradient increases, the air surrounding exposed sharp points is increasingly ionized. If the ionization is sufficient, coronal discharges may occur. The induced charge from a nearby lightning stroke may aid such a discharge. Such a discharge may be severe when lightning storms or cumulus development are within about 16 km (10 miles) of the launch pad.

9.1.7 Ground Current.

When lightning strikes an object, the current will flow through a path to the true earth. The voltage drop along this path may be great enough over short distances to be dangerous to personnel and equipment. Cattle and humans have been electrocuted from the current flow through the ground between two feet while standing under a tree, when the tree was hit by lightning.

9.2 Static Electricity.

A static electric charge can result from motion of an object through air containing dust or snow particles, or by wind-borne dust (often too small to be visible) or snow particles striking the object. This charge builds up until a potential is reached sufficiently high to bridge an air gap and so permit the charge to be carried to the ground. A discharge of potential will then occur, and may cause the ignition of explosive gases or interference in radio communications. This type of discharge, which occurs more frequently during periods of low humidities, is best prevented by grounding all metallic parts.

Static electric discharges can be expected at all geographical areas of concern.

9.3 Breakdown Voltage.

The breakdown voltage (voltage required for a spark to jump a gap) is a function of the atmospheric pressure. The breakdown voltage decreases to a minimum of 327 volts mm^{-1} at an atmospheric pressure of 760 newtons m^{-2} (7.6 mb) representing an altitude of 33.3 km. Above and below this altitude, the breakdown voltage increases rapidly, reaching several thousand volts per millimeter at normal atmospheric pressure as shown in Figure 9.1 (Ref. 9.7).

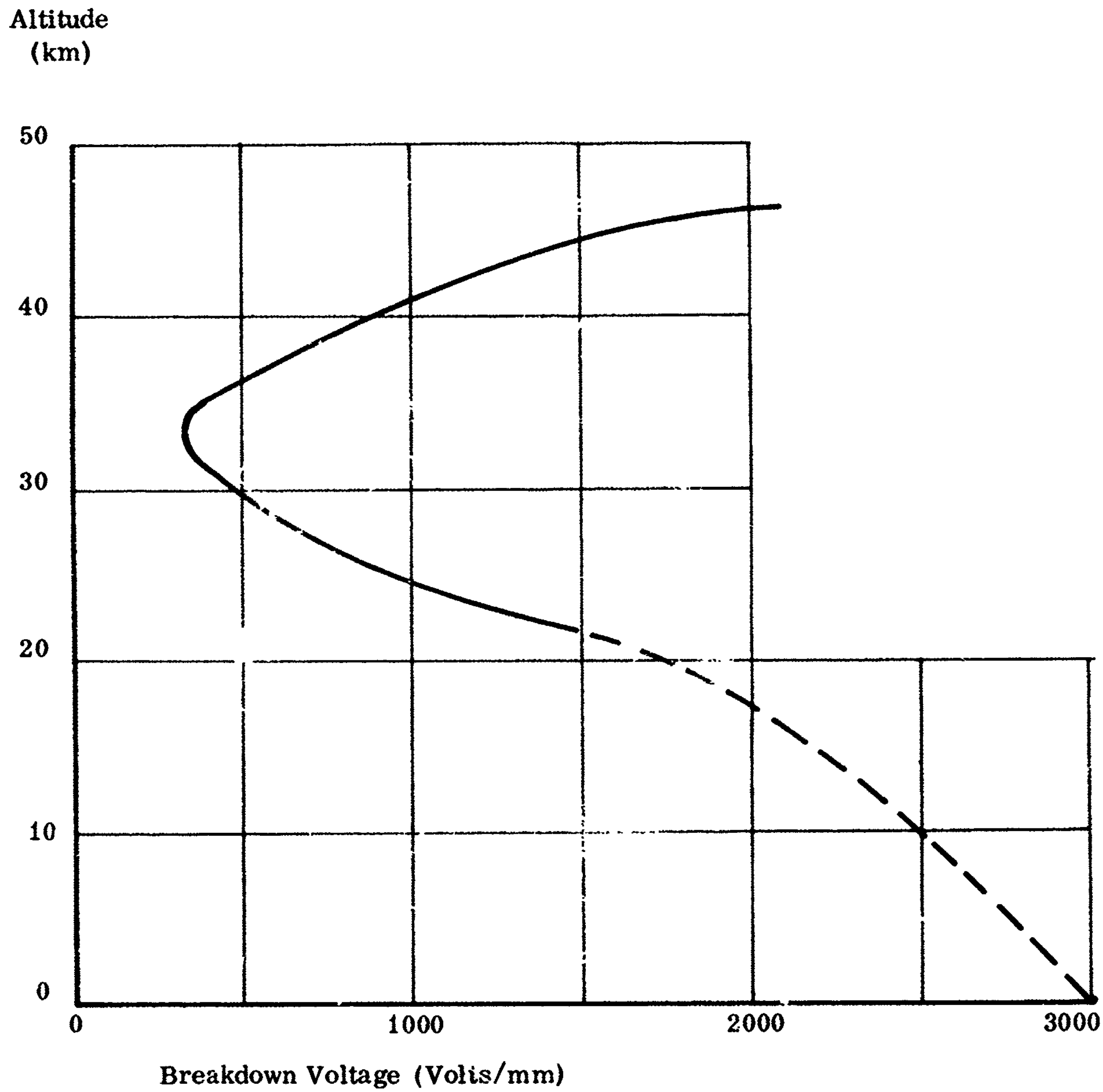

FIGURE 9.1. BREAKDOWN VOLTAGE VS ALTITUDE

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SECTION X. ATMOSPHERIC CORROSION

By

Glenn E. Daniels

10.1 Introduction.

The atmosphere, near the ocean, will cause galvanic corrosion of exposed metals. Wind moving over breaking sea waves will pick up small droplets of salt water. These droplets are small enough to remain suspended in the air. Some will evaporate and leave tiny particles of salt in the air. When these droplets and particles accumulate on surfaces and dry, a film of salt remains on the surface. If this film of salt is on an optical surface, its efficiency will be considerably reduced over periods of time. When the relative humidity is near saturation, or when light rain or drizzle occurs, the salt on the surface will absorb water and form a highly conductive solution. Corrosion by electrolytic action can result when two dissimilar metals are involved, and corrosion of a single metal can occur when the solution can react chemically. This solution can provide a conductive electrical path and short electrical equipment.

10.2 Corrosion.

The amount of corrosion is a function of several factors. Among the most important factors are (Ref. 10.1):

a. The distance of the exposed site from the ocean.

b. The length of time the humidity is high--the longer a material is wet, the more the corrosion.

c. Air temperature.

d. Elevation above sea level affects the corrosion in the first few feet above ground.

e. Corrosion is dependent on exposure direction, shelter around or near the material, and the direction and magnitude of the prevailing winds.

10.2.1 Laboratory Salt Spray Tests.

Methods have been devised to simulate the effects of salt spray in the laboratory. The following procedures have been taken from MIL-STD-810, Method 509 (Ref. 10.2), (Federal Test Method Standard No. 151; Method 811 has slight differences):

a. A salt solution is formed under the following conditions:

(1) Five percent sodium chloride in distilled water.

(2) pH between 6.5 and 7.2 and specific gravity from 1.027 to 1.041 when measured at a temperature between 33.3° and 36.1° C (92° and 97° F).

b. An air temperature of 35.0° C (95° F) is maintained in the test chamber.

c. The salt solution is atomized and applied so that 0.5 to 3.0 milliliters (0.015 to 0.10 fluid ounces) of solution will collect over an 80-square-centimeter (12.4 square in.) horizontal area in 1 hour.

d. The time of exposure of the test material is 168 hours. Such a test is assumed to be equal to about 1 year of natural exposure to salt spray.

e. Increasing the salt concentration will not accelerate the test.

Acceptance of the laboratory tests as an exact representation of the corrosion which will occur at a specific site may result in erroneous conclusions.

In any area where corrosion by the atmosphere can be an important factor, on-the-spot tests are needed. A test such as "Sample's wire-on-bolt test " (Ref. 10.3) should be conducted on the site, with tests made at various heights above the ground.

Protection from salt spray corrosion will be required in the following areas:

(1) New Orleans

(2) Gulf Transportation

(3) Eastern Test Range

(4) Panama Canal Transportation

(5) Western Test Range

(6) West Coast Transportation

(7) Sacramento

(8) Wallops Test Range

10.3 Obscuration of Optical Surfaces.

The accumulation of salt on exposed surfaces is greatest during onshore winds when many waves are breaking and forming white caps. Extremes expected are as follows (Ref. 10.4):

a. Particle size: Range from 0.1 to 20 microns, with 98 percent of the total mass greater than 0.8 microns.

b. Distribution is uniform to above 3048 meters (10,000 ft), but below cloud levels.

c. Fallout of salt particles at Eastern Test Range:

(1) Maximum: 5.0×10^{-7} g cm^{-2} day^{-1}, to produce a coating on an exposed surface of 100 microns day^{-1}. This extreme occurs during precipitation.

(2) Minimum: 2.5×10^{-8} g cm^{-2} day^{-1}, to produce a coating on an exposed surface averaging 5 microns day^{-1}. This occurs without precipitation from wind from any direction and is nearly continuous. This coating will not usually be of uniform thickness, but be spots of salt particles unevenly distributed over the optical surface.

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SECTION XI. FUNGI AND BACTERIA

By

Glenn E. Daniels

Fungi (including mold) and bacteria have the highest rate of growth at temperatures between 20.0°C (68°F) and 37.7°C (100°F) and relative humidities between 75 and 95 percent (Refs. 11.1 and 11.2). Fungi and bacteria secrete enzymes and acids during their growth. These secretions can destroy most organic substances and many of their derivatives. Typical materials which will support growth of fungi and bacteria and are damaged by them if not properly protected are cotton, wood, linen, leather, paper, cork, hair, felt, lens-coating material, paints, and metals. The four groups of fungi used in the fungus-resistance tests for equipment are as follows:

Group	Organism	American Type Culture Collection Number
I	Chaetomuim globosum	6205
	Myrothecium verrucaria	9095
II	Memenialla echinata	9597
	Aspergillus niger	6275
III	Aspergillus flavus	10836
	Aspergillus terreus	10690
IV	Penicillium citrinum	9849
	Penicillium ochrochloron	9112

A suspension of mixed spores made from one species of fungus from each group is sprayed on the equipment being tested in a test chamber. The equipment is then left for 28 days in the test chamber at a temperature of 30° ± 2°C (86° ± 3.6°F) and relative humidity of 95 ± 5 percent.

Equipment is usually protected from fungi and bacteria by incorporating a fungicide-bactericide in the material, by a fungicide-bactericide spray, or by reducing the relative humidity to a degree where growth will not take place. A

unique method used in the Canal Zone to protect delicate, expensive bearings in equipment was to maintain a pressure (with dry air or nitrogen) slightly above the outside atmosphere (few millibars) within the working parts of the equipment, thus preventing fungi from entering equipment.

Proper fungus- and bacteria-proofing measures are required at the following areas:

(1) River Transportation

(2) New Orleans

(3) Gulf Transportation

(4) Panama Canal Transportation

(5) Eastern Test Range

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SECTION XII. ATMOSPHERIC OXIDANTS

By

Glenn E. Daniels

12.1 Introduction.

Air pollution at the earth's surface has received considerable publicity in recent years because the pollutants reduce visibility, cause damage to crops, irritate the eyes, and have an objectional odor. The ingredients which cause the air pollution are a mixture of oxides of organic matter (mostly nitrogen oxides and hydrocarbons) and ozone. In the Los Angeles area, the mixing of the organic oxides, ozone, and water droplets forms the well known smog. Ozone, although considered one of the rare atmospheric gases, needs consideration in design because of its chemical reactivity (oxidation) with organic materials, especially rubber, which becomes hard and brittle under tension in a few minutes time. The presence in smog of strong oxidizing agents closely resembling ozone in their action on organic compounds leads one to believe that ozone exists in smog in greater quantities than in the normal atmosphere.

12.2 Ozone.

Ozone, in high concentrations, is explosive and poisonous. One part per million of ozone is toxic to man. The use of the atmosphere at high altitudes for breathing by pressurizing, requires removal of the ozone. Ozone may be formed in high concentrations by short wavelength ultraviolet light (below 2537Å), or by the arcing or discharge of electrical currents. A motor or generator with arcing brushes is an excellent source of ozone. The natural ozone concentration at the earth's surface is normally less than 3 parts per hundred million (phm), except during periods of intense smog, where it may exceed 5 phm. Ozone concentration increases with altitude, with the maximum concentration being at about 30 km (98,000 ft).

Maximum values of natural atmospheric ozone, for purposes of design studies, are as follows: (a) surface, at all areas, a maximum concentration of three phm except during smog, when the maximum will be six phm, and (b) maximum concentration, with altitude, is given in Table 12.1 (Ref. 12.1).

TABLE 12.1 DISTRIBUTION OF MAXIMUM VALUES OF OZONE CONCENTRATION WITH ALTITUDE FOR ALL LOCATIONS

Geometric Altitude (km)	Geometric Altitude (ft)	Ozone (parts per hundred million)	Ozone Concentration (cm/km)
SRF*	SRF*	6	0.006
9.1	30,000	30	0.010
15.2	50,000	200	0.030
21.3	70,000	700	0.040
27.4	90,000	1100	0.024
33.5	110,000	1100	0.009
39.6	130,000	600	0.002
45.7	150,000	400	0.0005

*SRF - Surface

12.3 Atmospheric Oxidants.

At the surface, a maximum of 60 parts per hundred million of oxidants composed of nitrogen oxides, hydrocarbons, sulphur dioxide, sulphur trioxides, peroxides, and ozone can be expected for 72 hours when smog occurs. The effect of these oxidants on rubber cracking and in some chemical reactions will be equivalent to 22 parts per hundred million of ozone, but not necessarily equivalent to this concentration of ozone in other reactions (Ref. 12.2).

REFERENCES

12.1 Ditaranto, R. A.; and Lamb, J. J.: "Preliminary Investigation of Hyper-Environments and Methods of Simulation, Part I, Natural and Induced Environments Above 75,000 ft." WADC Technical Report 57-456, Part I, ASTIA Doc. No. AD-142002, 1957.

12.2 Haagen-Smit, A. J.: "Chemistry and Physiology of Los Angeles Smog." Industrial and Engineering Chemistry, vol. 44, no. 6, June 1952, pp. 1342-1346.

SECTION XIII. ATMOSPHERIC COMPOSITION

By

Glenn E. Daniels

13. 1 Composition.

The earth's atmosphere is made up of a number of gases in different relative amounts. Near sea level and up to about 90 km, the amount of these atmospheric gases in clean dry air is practically constant. Four of these gases, nitrogen, oxygen, argon, and carbon dioxide, make up 99. 99 percent by volume of the atmosphere. Two gases, ozone and water vapor, change in relative amounts, but the total amount of these two is very small compared to the amount of the other gases.

The atmospheric composition shown in Table 13. 1 can be considered valid up to 90 km geometric altitude.

Above 90 km, mainly because of molecular dissociation and diffusive separation, the composition changes from that shown in Table 13. 1.

13. 2 Molecular Weight.

The atmospheric composition shown in Table 13. 1 gives a molecular weight of 28. 9644 for dry air (Ref. 13. 1). This value of molecular weight can be used as constant up to 90 km, and is equivalent to the value 28. 966 on the basis of a molecular weight of 16 for oxygen.

The molecular weight of the atmosphere with relation to height is shown in Table 13. 2.

TABLE 13.1 NORMAL ATMOSPHERIC COMPOSITION FOR CLEAN, DRY AIR AT ALL LOCATIONS (VALID TO 90 KILOMETERS GEOMETRIC ALTITUDE)

Gas	Percent by Volume	Percent by Weight*
Nitrogen (N_2)	78.084	75.520
Oxygen (O_2)	20.9476	23.142
Argon (Ar)	0.934	1.288
Carbon dioxide (CO_2)	0.0314	0.048
Neon (Ne)	1.818×10^{-3}	1.27×10^{-3}
Helium (He)	5.24×10^{-4}	7.24×10^{-5}
Krypton (Kr)	1.14×10^{-4}	3.30×10^{-4}
Xenon (Xe)	8.7×10^{-6}	3.9×10^{-5}
Hydrogen (H_2)	5×10^{-5}	3×10^{-6}
Methane (CH_4)	2×10^{-4}	1×10^{-4}
Nitrous Oxide (N_2O)	5×10^{-5}	8×10^{-5}
Ozone (O_3) summer	0 to 7×10^{-6}	0 to 1.1×10^{-5}
winter	0 to 2×10^{-6}	0 to 3×10^{-6}
Sulfur dioxide (SO_2)	0 to 1×10^{-4}	0 to 2×10^{-4}
Nitrogen dioxide (NO_2)	0 to 2×10^{-6}	0 to 3×10^{-6}
Ammonia (NH_3)	0 to trace	0 to trace
Carbon monoxide (CO)	0 to trace	0 to trace
Iodine (I_2)	0 to 1×10^{-6}	0 to 9×10^{-6}

*On basis of Carbon 12 isotope scale for which $C^{12} = 12.000$, as adopted by the International Union of Pure and Applied Chemistry meeting, Montreal, in 1961.

TABLE 13.2 MOLECULAR WEIGHT OF THE ATMOSPHERE FOR ALL LOCATIONS

Geometric Altitude (km)	(ft)	Molecular Weight
SRF* to 90	SRF* to 295,000	28.9644 28.9644
100	328,000	28.88

*SRF - Surface

REFERENCES

13.1 "U. S. Standard Atmosphere, 1962." United States Government Printing Office, Washington 25, D.C., 1962.

SECTION XIV. INFLIGHT THERMODYNAMIC PROPERTIES

By

Orvel E. Smith

14.1 Introduction

This section presents the inflight thermodynamic properties (temperature, pressure, and density) of the atmosphere. The first part gives median and extreme values of these thermodynamic variables with relation to altitude. In the last part of this section, data are presented for temperature, pressure, and density as independent variables with a method to obtain simultaneous values of these variables at discrete altitude levels.

14.2 Temperature

14.2.1 Air Temperature at Altitude.

a. Eastern Test Range air temperature extreme values with altitude are given in Table 14.1 (Ref. 14.1).

b. Western Test Range air temperature extreme values with altitude are given in Table 14.2.

c. Wallops Test Range air temperature extreme values with altitude are given in Table 14.3.

d. White Sands Missile Range air temperature extreme values with altitude are given in Table 14.4.

14.2.2 Compartment Extreme Cold Temperature.

Extreme cold temperatures during aircraft flight, when compartments are not heated, are given in Table 14.5

TABLE 14.1 EASTERN TEST RANGE AIR TEMPERATURES AT VARIOUS ALTITUDES

Geometric Altitude (km)	Minimum (°C)	Minimum (°F)	Median (°C)	Median (°F)	Maximum (°C)	Maximum (°F)
SRF(0.005 MSL)	- 2.2	28	23.9	75	37.2	99
1	- 8.9	16	17.2	63	27.8	82
2	-10.0	14	12.2	54	21.1	70
3	-11.1	12	7.2	45	16.1	61
4	-13.9	7	2.2	36	11.1	52
5	-20.0	- 4	- 3.9	25	5.0	41
6	-26.1	- 15	-10.0	14	- 1.1	30
7	-33.9	- 29	-17.2	1	- 7.2	19
8	-41.1	- 42	-25.0	-13	-13.9	7
9	-50.0	- 58	-32.2	-26	-21.1	- 6
10	-56.1	- 69	-40.0	-40	-30.0	-22
16.2	-80.0	-112	-70.0	-94	-57.8	-72
20	-76.1	-105	-62.8	-81	-47.8	-54
30	-58.9	- 74	-42.2	-44	-30.0	-22
40	-30.0	- 22	-17.8	0	2.2	36
50	-15.0	5	- 2.2	28	26.1	79
59	-37.8	- 36	-20.0	- 4	27.8	82
			*			

* For higher altitudes see reference 14.1

TABLE 14.2 WESTERN TEST RANGE AIR TEMPERATURES AT VARIOUS ALTITUDES

Geometric Altitude (km)	Minimum (°C)	Minimum (°F)	Median (°C)	Median (°F)	Maximum (°C)	Maximum (°F)
SRF(0.06 MSL)	- 2.2	28.0	12.6	54.7	41.7	107.0
1	- 3.6	25.5	13.5	56.3	33.4	92.1
2	- 7.0	19.4	10.1	50.2	28.0	82.4
3	-15.2	4.6	4.7	40.5	17.6	63.7
4	-22.6	- 8.7	- 0.9	30.4	12.1	53.8
5	-29.7	- 21.5	- 7.2	19.0	3.3	37.9
6	-35.6	- 32.1	-14.4	6.1	- 2.7	27.1
7	-43.3	- 45.9	-21.9	- 7.4	- 9.9	14.2
8	-47.4	- 53.3	-29.8	-21.6	-15.9	3.4
9	-51.3	- 60.3	-36.9	-34.4	-26.8	-16.2
10	-57.0	- 70.6	-44.6	-48.3	-31.2	-24.2
16.3	-76.0	-104.8	-64.1	-83.4	-51.0	-59.8
20	-74.9	-102.8	-59.5	-75.1	-49.0	-56.2
30	-63.7	- 82.7	-42.5	-44.5	-29.4	-20.9
			**			

** For higher altitudes see reference 14.2 and 14.3

TABLE 14.3 WALLOPS TEST RANGE AIR TEMPERATURES AT VARIOUS ALTITUDES.

Geometric Altitude (km)	Minimum (°C)	Minimum (°F)	Median (°C)	Median (°F)	Maximum (°C)	Maximum (°F)
SRF(0.002 MSL)	-11.7	11	12.8	55	39.4	103
1	-21.1	- 6	10.0	50	31.1	88
2	-26.1	- 15	5.0	41	22.8	73
3	-30.0	- 22	1.1	34	15.0	59
4	-33.9	- 29	- 3.9	25	7.8	46
5	-40.0	- 40	-10.0	14	2.8	37
6	-43.9	- 47	-17.2	1	- 1.1	30
7	-47.8	- 54	-23.9	-11	- 7.8	18
8	-50.6	- 59	-32.2	-26	-15.0	5
9	-56.1	- 69	-38.9	-38	-21.1	- 6
10	-61.1	- 78	-45.0	-49	-27.2	-17
16.5	-77.8	-108	-62.2	-80	-47.2	-53
20	-71.1	- 96	-57.2	-71	-46.1	-51
30	-65.0	- 85	-43.9	-47	-27.2	-17
40*	-36.1	- 33	-12.2	10	6.1	43
44*	-20.0	- 4	0.0	32	17.2	63
50*	-22.2	- 8	-10.0	14	5.0	41
56*	-22.2	- 8	-11.1	12	5.0	41
			**			

* Values based on less than 10 observations.
** For higher altitudes see references 14.2 and 14.3

TABLE 14.4 WHITE SANDS MISSILE RANGE AIR TEMPERATURES AT VARIOUS ALTITUDES

Geometric Altitude (km)	Minimum (°C)	Minimum (°F)	Median (°C)	Median (°F)	Maximum (°C)	Maximum (°F)
SRF(1.2 MSL)	-11.7	11	16.1	61	42.8	109
2	-11.7	11	12.8	55	31.1	88
3	-18.9	- 2	6.1	43	22.2	72
4	-23.9	- 11	0.0	32	12.8	55
5	-31.1	- 24	- 7.2	19	6.1	43
6	-36.1	- 33	-13.9	7	0.0	32
7	-42.2	- 44	-20.0	- 4	- 7.2	19
8	-48.9	- 56	-30.0	-22	-13.9	7
9	-55.0	- 67	-37.2	-35	-21.1	- 6
10	-60.0	- 76	-42.8	-45	-27.2	-17
16.5	-80.0	-112	-67.2	-89	-47.8	-54
20	-77.8	-108	-60.0	-76	-52.2	-62
30	-58.9	- 74	-42.8	-45	-26.1	-15
40	-40.0	- 40	-13.9	7	20.0	68
50	-22.8	- 9	6.1	43	17.8	64
60	- 5.0	23	7.2	45	25.0	77
65	- 5.0	23	8.9	48	17.8	64
			*			

* For higher altitudes see references 14.2 and 14.3.

TABLE 14.5 COMPARTMENT DESIGN COLD TEMPERATURE EXTREMES FOR ALL LOCATIONS

Maximum Flight Altitude (Geometric) Of Aircraft Used For Transport		Compartment Cold Temperature Extreme	
(m)	(ft)	(°C)	(°F)
4,550	15,000	-35.0	-31
6,100	20,000	-45.0	-49
7,600	25,000	-53.3	-64
9,150	30,000	-65.0	-85
15,200	50,000	-86.1	-123

14.3 Atmospheric Pressure

14.3.1 Definition.

Atmospheric pressure (also called barometric pressure) is the force exerted as a consequence of gravitational attraction, by the mass of the column of air of unit cross section lying directly above the area in question. It is expressed as force per unit area.

14.3.2 Pressure at Altitude.

Atmospheric pressure extremes for all locations are given in Table 14.6.

14.4 Atmospheric Density.

14.4.1 Definition.

Density is the ratio of the mass of a substance to its volume. (It also is defined as the reciprocal of specific volume.) Density is usually expressed in grams or kilograms per cubic centimeter or cubic meter.

14.4.2 Atmospheric Density at Altitude.

14.4.2.1 The density of the atmosphere decreases rapidly with height, decreasing to one-half that of the surface at 7 km altitude. Density also is variable at a fixed altitude, with the greatest relative variability occurring at about 70 km altitude in the high northern latitudes (60°N) for altitude ranges up to 90 km.

TABLE 14.6 ATMOSPHERIC PRESSURE-HEIGHT EXTREMES FOR ALL LOCATIONS

Geometric Altitude (above mean sea level)		Pressure					
		Maximum		Median		Minimum	
(km)	(ft)	(mb)	(lb in.$^{-2}$)	(mb)	(lb in.$^{-2}$)	(mb)	(lb in.$^{-2}$)
0	0	(Use values in Table 7.1 for surface pressure for each station)					
3	9,800	730	10.6	714	10.4	680	9.86
6	19,700	510	7.40	490	7.11	460	6.67
10	32,800	295	4.28	283	4.10	255	3.70
15	49,200	135	1.96	129	1.87	118	1.71
20	65,600	60	8.7×10^{-1}	56	8.1×10^{-1}	51	7.4×10^{-1}
25	82,000	30	4.4×10^{-1}	28	4.1×10^{-1}	22	3.2×10^{-1}
30	98,400	12.5	1.8×10^{-1}	11.7	1.7×10^{-1}	11.2	1.6×10^{-1}
40	131,000	2.9	4.2×10^{-2}	3.0	4.4×10^{-2}	2.5	3.6×10^{-2}
50*	164,000	1.2	1.7×10^{-2}	8.5×10^{-1}	1.2×10^{-2}	1.5×10^{-1}	2.2×10^{-3}
75*	246,000	7.5×10^{-2}	1.1×10^{-3}	2.5×10^{-2}	3.6×10^{-4}	2.5×10^{-4}	3.6×10^{-6}
100*	328,000	2.5×10^{-3}	3.6×10^{-5}	3.2×10^{-4}	4.5×10^{-6}	7.2×10^{-6}	1.0×10^{-7}

* Median values from
reference 14.2, maximum and minimum values estimated.

14.4.2.2 Considerable data are now available on the mean density and its variability below 30 km at the various test ranges from the data collected for preparation of the IRIG Range Reference Atmospheres (Ref. 14.4). Additional information on the seasonal variability of density below 30 km is presented in an article by J. W. Smith (Ref. 14.5).

14.4.2.3 Above 30 km, the data are less plentiful and the accuracy of the temperature measurements (used to compute densities) becomes poorer with altitude.

14.4.2.4 The median density and extreme minimum and maximum values for the Eastern Test Range are given in Table 14.7.

14.4.2.5 Density varies with latitude, with the mean annual density near the surface increasing to the north. In the region around 8 km, the density variation with latitude is small. This is also a region of minimum seasonal variation (isopycnic level). Above 8 km to about 28 km the mean annual density decreases towards the north. Mean-monthly densities between 30 km and 90 km increase toward the north in July and the south in January.

14.4.2.6 The maximum, minimum and median densities for 3 km and above, given in Table 14.7, can be used for all locations given in par 1.5 with an adjustment of the surface median density using the values given in Table 8.1, Section VIII, reduced to sea level.

14.4.2.7 The units for density (kg m-3) were changed from those used in TM X-53023 (Ref. 14.6) to have consistent units with those given in the Patrick Reference Atmosphere (1963 Revision) included in Table 14.9 of this document. Density deviations were found as follows:

$$\% \text{ Deviation } \Delta\rho = \frac{\rho_{\text{max or min}} - \rho_{\text{PRA 63}}}{\rho_{\text{PRA 63}}} \times 100$$

where

$\Delta\rho$ = Deviation of density from the Patrick Reference Atmosphere 1963

$\rho_{\text{PRA 63}}$ = Patrick Reference Atmosphere 1963 density = median density

$\rho_{\text{max or min}}$ = Given maximum or minimum densities.

TABLE 14.7 DENSITY HEIGHT MAXIMUM (≈ + 3 SIGMA), MINIMUMS (≈ - 3 SIGMA) AND MEDIANS FOR EASTERN TEST RANGE

Altitude **		Density							
		Maximum***			Median*		Minimum***		
(km)	(ft)	(kg m^{-3})	(lb ft^{-3})	(% Deviation #)	(kg m^{-3})	(lb ft^{-3})	(% Deviation #)	(kg m^{-3})	(lb ft^{-3})
0	0	1.326	8.278×10^{-2}	12.0	1.1835	7.388×10^{-2}	3.6	1.141	7.123×10^{-2}
2	6,600	1.047	6.536×10^{-2}	6.1	9.7903×10^{-1}	6.112×10^{-2}	3.0	9.497×10^{-1}	5.929×10^{-2}
4	13,100	8.287×10^{-1}	5.174×10^{-2}	3.7	7.9916×10^{-1}	4.989×10^{-1}	2.1	7.824×10^{-1}	4.885×10^{-2}
6	19,700	6.706×10^{-1}	4.187×10^{-2}	3.2	6.4983×10^{-1}	4.057×10^{-2}	2.2	6.355×10^{-1}	3.967×10^{-2}
8	26,200	5.428×10^{-1}	3.389×10^{-2}	3.1	5.2652×10^{-1}	3.287×10^{-2}	4.0	5.055×10^{-1}	3.156×10^{-2}
10	32,800	4.352×10^{-1}	2.717×10^{-2}	3.0	4.2255×10^{-1}	2.638×10^{-2}	6.8	3.938×10^{-1}	2.458×10^{-2}
15	49,200	2.345×10^{-1}	1.464×10^{-2}	7.0	2.1920×10^{-1}	1.368×10^{-2}	9.7	1.979×10^{-1}	1.235×10^{-2}
20	65,600	1.002×10^{-1}	6.255×10^{-3}	7.5	9.3194×10^{-2}	5.818×10^{-3}	6.1	8.751×10^{-2}	5.463×10^{-3}
25	82,000	4.274×10^{-2}	2.668×10^{-3}	5.9	4.0358×10^{-2}	2.520×10^{-3}	6.1	3.790×10^{-2}	2.366×10^{-3}
30	98,400	1.976×10^{-2}	1.234×10^{-3}	7.8	1.8334×10^{-2}	1.145×10^{-3}	7.3	1.700×10^{-2}	1.061×10^{-3}
35	115,000	9.427×10^{-3}	5.885×10^{-4}	10.3	8.5464×10^{-3}	5.336×10^{-4}	10.6	7.640×10^{-3}	4.770×10^{-4}
40	131,200	4.637×10^{-3}	2.895×10^{-4}	12.5	4.1220×10^{-3}	2.573×10^{-4}	14.8	3.512×10^{-3}	2.193×10^{-4}
50	164,000	1.275×10^{-3}	7.960×10^{-5}	16.3	1.0963×10^{-3}	6.846×10^{-5}	21.3	8.630×10^{-4}	5.388×10^{-5}
60	196,800	3.946×10^{-4}	2.463×10^{-5}	19.4	3.3049×10^{-4}	2.063×10^{-5}	25.4	2.465×10^{-4}	1.539×10^{-5}
70	229,700	1.100×10^{-4}	6.867×10^{-6}	23.6	8.8998×10^{-5}	5.556×10^{-6}	25.1	6.666×10^{-5}	4.162×10^{-6}
80	262,500	2.342×10^{-5}	1.462×10^{-6}	19.0	1.9677×10^{-5}	1.228×10^{-6}	18.9	1.596×10^{-5}	9.964×10^{-7}
90	295,000	3.684×10^{-6}	2.300×10^{-7}	10.9	3.3216×10^{-6}	2.074×10^{-7}	11.8	2.930×10^{-6}	1.829×10^{-7}
100	328,000	5.873×10^{-8}	3.667×10^{-8}	12.4	5.2254×10^{-7}	3.262×10^{-8}	13.2	4.536×10^{-7}	2.832×10^{-8}
110	360,900	1.186×10^{-7}	7.404×10^{-9}	14.6	1.0350×10^{-7}	6.462×10^{-9}	16.1	8.684×10^{-8}	5.421×10^{-9}
120	393,700	3.032×10^{-8}	1.893×10^{-9}	18.0	2.5692×10^{-8}	1.603×10^{-9}	19.0	2.081×10^{-8}	1.299×10^{-9}

* Median Values from NASA TM X-53139 (Ref. 14.1)
** Geometric Altitude above mean sea level
*** Maximum and minimum values from R-AERO-Y-48-65 (Ref. 14.7)

14.5 Simultaneous Values of Temperature, Pressure, and Density at Discrete Altitude Levels.

14.5.1 Introduction

This is the first attempt to present simultaneous values for temperature, pressure, and density as guidelines for aerospace vehicle design considerations. The necessary assumptions, and lack of sufficient statistical data sample restricts the precision by which these data can presently be presented. Therefore, the analysis is limited to the Eastern Test Range (Cape Kennedy, Florida).

14.5.2 Method of Determing Simultaneous Value

An aerospace vehicle design problem that often arises in considering natural environmental data is stated by way of the following question: "How should the extremes (maxima and minima) of temperature, pressure, and density be combined (a) at discrete altitude levels? (b) versus altitude?" It would seem simple to work with only three variables with respect to altitude that are connected by two physical equations which are (1) the equation of state and (2) the hydrostatic equation. However, it is these facts that makes rigorous statistical treatment of sample data impossible and the only recourse is to make empirical comparisons of results derived by independent methods. The following discussion will be addressed to the first question. "How should extremes of three variables be combined?" Or stated in another way: Given an extreme density, what values of temperature and pressure should be used simultaneously with the extreme density?

The differentiation of the equation of state yields:

$$\frac{d\rho}{\rho} = \frac{dP}{P} - \frac{dT}{T}. \qquad (14.1)$$

Equation (14.1) holds only if the departures $d\rho$, dP, and dT are small relative to their respective quantities. There is also a problem of how to treat the ± deviations. What is needed is the correlation coefficients between these variables. From basic statistical principles (Ref. 14.8) a satisfactory set of three equations can be derived to relate these three variables to each other. These equations are

$$\left(\frac{\sigma_T}{\overline{T}}\right) = \left(\frac{\sigma_P}{\overline{P}}\right) r(P\rho)\ r(\rho T) - \left(\frac{\sigma_\rho}{\overline{\rho}}\right) r(\rho T) \qquad (14.2)$$

$$\left(\frac{\sigma_P}{\overline{P}}\right) = \left(\frac{\sigma_\rho}{\overline{\rho}}\right) r(P\rho) + \left(\frac{\sigma_T}{\overline{T}}\right) \quad r(PT) \tag{14.3}$$

$$\left(\frac{\sigma_\rho}{\overline{\rho}}\right) = \left(\frac{\sigma_P}{\overline{P}}\right) r(PT)\ r(\rho T) - \left(\frac{\sigma_T}{\overline{T}}\right) r(\rho T). \tag{14.4}$$

Where

r( ) are correlation coefficients between thermodynamic quantities denoted in parenthesis.

σ is the standard deviation of the thermodynamic quantity denoted by subscript.

As written, equations (14.2), (14.3), and (14.4) represent population parameters and the underlying assumption is that the sample distribution is normal (Gaussian). From private communications with Dr. Buell* it was learned that in deriving these equations, second and higher order terms have been neglected. An application of these equations was made to derive the correlation coefficients using the available statistics for Cape Kennedy. In the development of the pole-to-pole cross sections for NASA TN D-1641 (Ref. 14.9), the means and standard deviations of temperature, pressure, and density were computed for several stations, including Cape Kennedy. From these statistics the sample estimates for

$$\frac{\sigma_T}{T}, \quad \frac{\sigma_P}{P}, \quad \frac{\sigma_\rho}{\rho} \quad \text{were computed.}$$

These parameters are called coefficients of variations. Using the sample coefficients of variations as known quantities, a simultaneous solution of equations (14.2), (14.3) and (14.4) can be obtained to yield the desired correlation coefficients. Viz,

$$r(P\rho) = \frac{\left(\frac{\sigma_\rho}{\overline{\rho}}\right)^2 - \left(\frac{\sigma_T}{\overline{T}}\right)^2 + \left(\frac{\sigma_P}{\overline{P}}\right)^2}{2\left[\left(\frac{\sigma_\rho}{\overline{\rho}}\right)\left(\frac{\sigma_P}{\overline{P}}\right)\right]} \tag{14.5a}$$

$$r(PT) = \frac{\left(\frac{\sigma_T}{\overline{T}}\right)^2 + \left(\frac{\sigma_P}{\overline{P}}\right)^2 - \left(\frac{\sigma_\rho}{\overline{\rho}}\right)^2}{2\left[\left(\frac{\sigma_T}{\overline{T}}\right)\left(\frac{\sigma_P}{\overline{P}}\right)\right]} \tag{14.5b}$$

* Dr. C. Eugene Buell, Kaman Nuclear, Colorado Springs, Colorado.

$$r(\rho T) = \frac{\left(\frac{\sigma_P}{\overline{P}}\right)^2 - \left(\frac{\sigma_\rho}{\overline{\rho}}\right)^2 - \left(\frac{\sigma_T}{\overline{T}}\right)^2}{2\left[\left(\frac{\sigma_T}{\overline{T}}\right)\left(\frac{\sigma_\rho}{\overline{\rho}}\right)\right]}. \tag{14.5c}$$

From equations (14.5a), (14.5b), and (14.5c) the correlation coefficients were computed for monthly and annual data samples at one-km intervals from 0 to 30 km altitude for Cape Kennedy and compared with the coefficients for Tampa, Florida (Ref. 14.10) derived in the standard method. The differences between the correlation coefficients were no greater than that which could be attributed to sampling fluctuations and precision of either method.

The values for the coefficient of variations and the derived correlation coefficients $r(P\rho)$, $r(PT)$, and $r(\rho T)$, are illustrated in figures 14.1 and 14.2, respectively, and given in Table 14.8. The density variability is a minimum at the isopycnic levels near 8 and 90 km altitude. The correlation coefficient between pressure and density is also a minimum at the isopycnic levels. Because of the meager data sample for statistical analysis at altitudes above 30 km, the coefficients of variation had to be adjusted by making several trial computations to yield correlation coefficients which were consistent with statistical theory. That is, the correlation coefficients must lie between ± 1. Even though no claim for accuracy can be made about the resulting data, we do have for the first time deviations for temperature, pressure, and density from 0 to 120 km altitude which are consistent in terms of a statistical method and a procedure whereby departures from the mean values of these quantities can be combined. As an example, suppose it is desired to know what temperature and pressure should be used simultaneously with a maximum density. Solution: Let the mean density plus 3 standard deviations represent the extreme density. From the foregoing equations it is seen that

$$(\overline{\rho} + 3\sigma_\rho) = \overline{\rho}\left[1 + 3\frac{\sigma_\rho}{\overline{\rho}}\right]$$

$$= \overline{\rho}\left[1 + 3\left\{\left(\frac{\sigma_P}{\overline{P}}\right) r(PT)\, r(\rho T) - \left(\frac{\sigma_T}{\overline{T}}\right) r(\rho T)\right\}\right]. \tag{14.6}$$

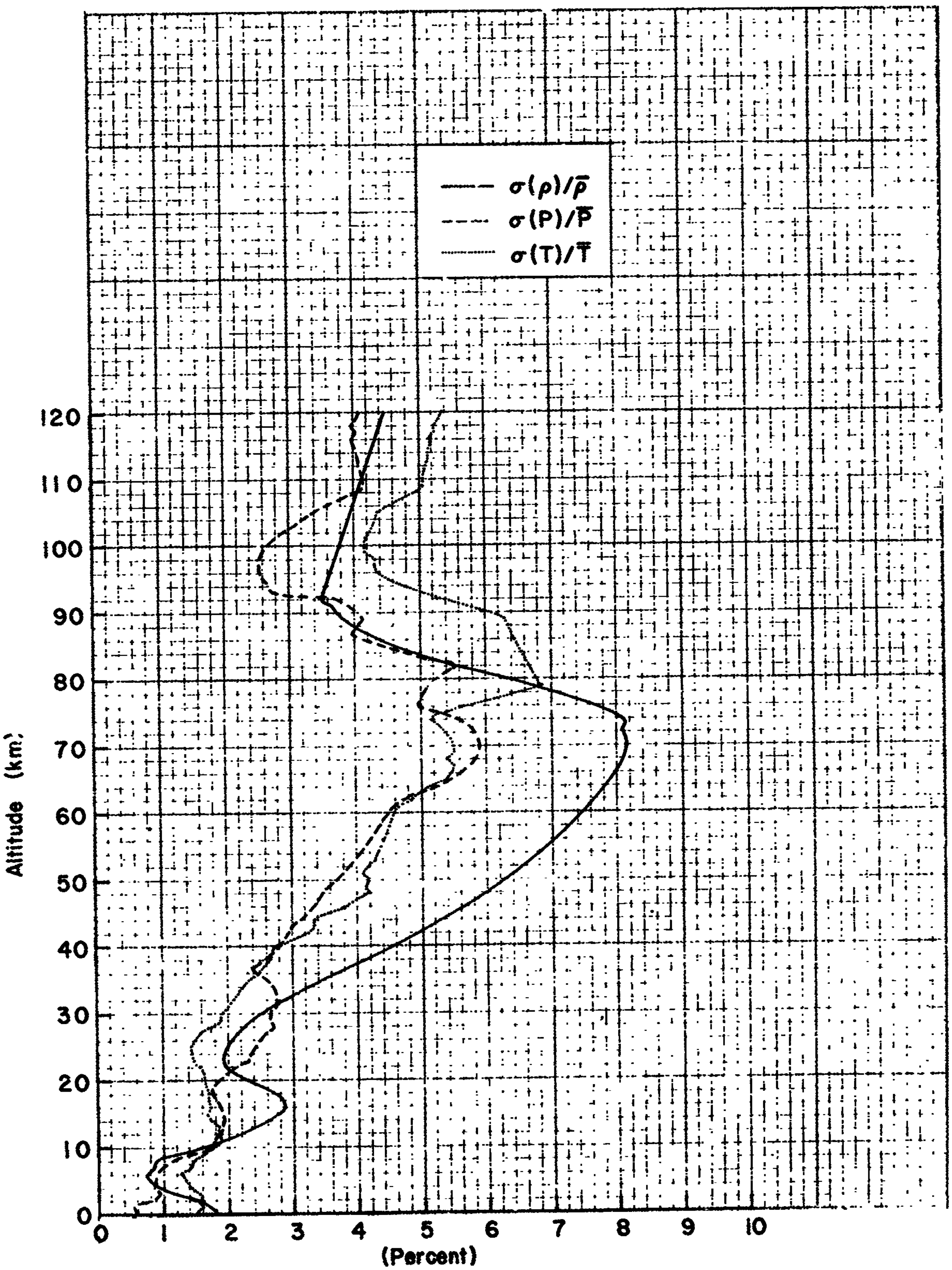

Figure 14.1 Coefficient of Variation of Density, Pressure, and Temperature at Eastern Test Range (Cape Kennedy, Florida), Annual.

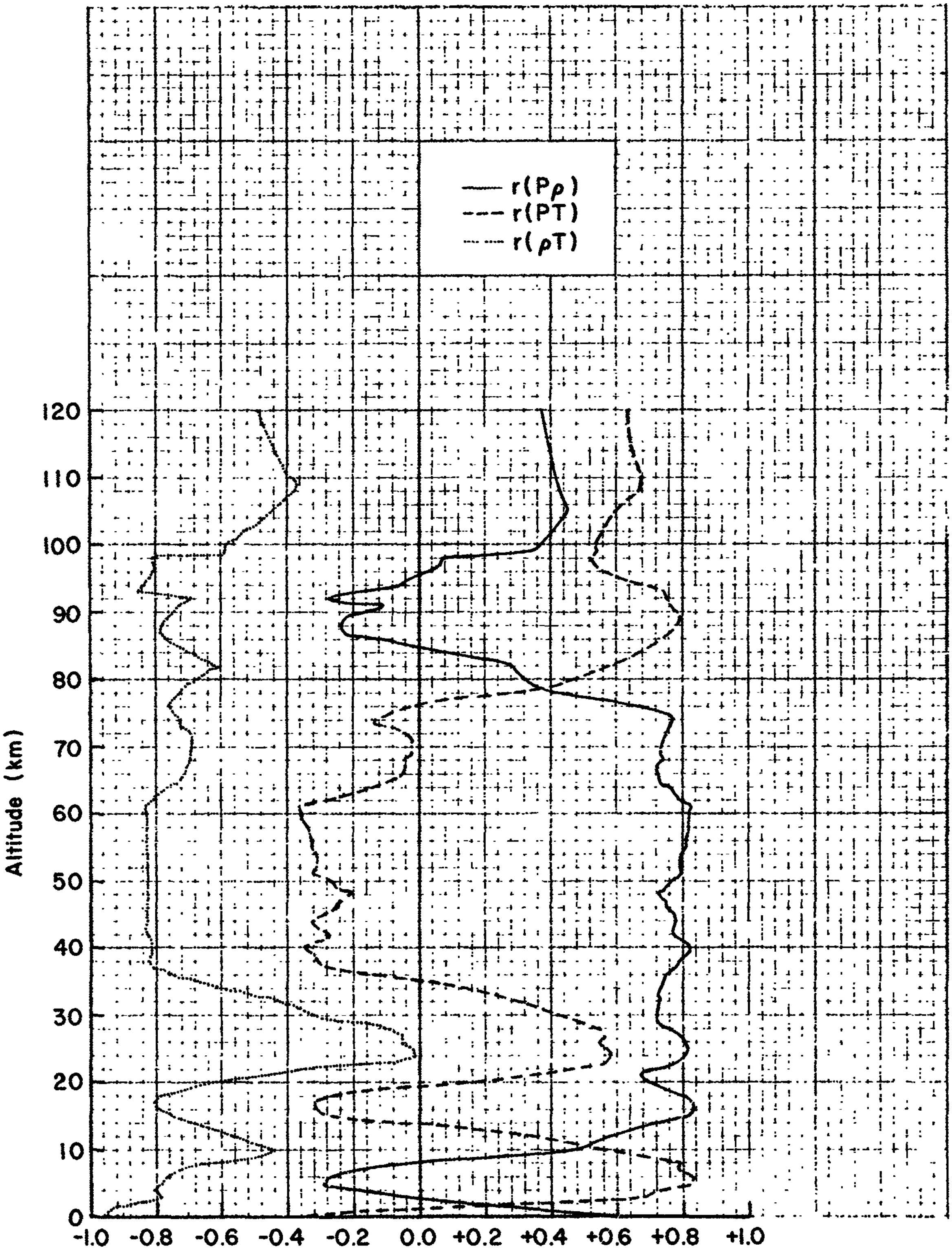

Figure 14.2 Discrete Altitude Level Correlation Coefficients Between Pressure-Density, r(Pρ); Pressure-Temperature, r(PT); and Density-Temperature, r(ρT) at Eastern Test Range (Cape Kennedy, Florida), Annual. *

TABLE 14.8 COEFFICIENTS OF VARIATION AND DISCRETE ALTITUDE LEVEL CORRELATION COEFFICIENTS BETWEEN PRESSURE - DENSITY r(Pρ); PRESSURE - TEMPERATURE r(PT); AND DENSITY - TEMPERATURE r(ρT), EASTERN TEST RANGE (CAPE KENNEDY, FLORIDA), ANNUAL

ALTITUDE	COEFFICIENTS OF VARIATION			CORRELATION COEFFICIENTS		
(km)	$\sigma(\rho)/\bar{\rho}$ (percent)	$\sigma(P)/\bar{P}$ (percent)	$\sigma(T)/\bar{T}$ (percent)	r(Pρ) (unitless)	r(PT) (unitless)	r(ρT) (unitless)
0	1.8000	.6000	1.5000	.6250	-0.3500	-0.9500
1	1.7000	.5500	1.6000	.3382	-0.0[illegible]36	-0.9462
2	1.5000	.8000	1.5900	.1508	.3609	-0.8675
3	1.1800	.9800	1.5700	-0.0485	.6606	0.7818
4	.9700	.8500	1.4000	-0.1799	.7318	-0.8021
5	.8000	.8700	1.3400	-0.2864	.8203	-0.7830
6	.7400	.8400	1.2600	-0.2690	.8246	-0.7666
7	.8800	.9800	1.4200	-0.1633	.7913	-0.7324
8	.9000	1.1300	1.4700	-0.0364	.7910	-0.6402
9	1.1800	1.4700	1.6200	.2678	.7124	-0.4854
10	1.6300	1.7500	1.7200	.4840	.5588	-0.4553
11	1.8800	1.8000	1.7800	.5328	.4485	-0.5174
12	2.1500	1.8700	1.8500	.5841	.3320	-0.5717
13	2.3800	1.9000	1.8500	.6470	.1946	-0.6220
14	2.6200	1.9200	1.7700	.7373	-0.0066	-0.6804
15	2.7800	1.8800	1.6700	.8107	-0.2238	-0.7520
16	2.8800	1.8400	1.7100	.8262	-0.3154	-0.7953
17	2.8800	1.8000	1.7000	.8338	-0.3537	-0.8113
18	2.7500	1.7500	1.7000	.8036	-0.2706	-0.7904
19	2.5000	1.7800	1.6700	.7449	-0.0492	-0.7031
20	2.2700	1.8500	1.6500	.6969	.1625	-0.5944
21	2.0800	1.9500	1.6200	.6786	.3325	-0.4672
22	1.9800	2.1200	1.5700	.7087	.4565	-0.3041
23	1.9200	2.3200	1.4800	.7721	.5659	-0.0870
24	1.9500	2.4000	1.4300	.8032	.5831	-0.0157
25	2.000	2.4300	1.4200	.8116	.5682	-0.0196
26	2.0800	2.5000	1.5000	.8006	.5565	-0.0523
27	2.1500	2.6000	1.5800	.7948	.5640	-0.0528
28	2.2300	2.6700	1.7500	.7591	.5584	-0.1161
29	2.3700	2.6300	1.8700	.7249	.4877	-0.2479
30	2.5200	2.6300	1.9200	.7228	.4211	-0.3224
31	2.7000	2.7000	2.000	.7257	.3704	-0.3704
32	2.8800	2.7500	2.0800	.7279	.3142	-0.4222
33	3.0700	2.7300	2.1700	.7260	.2310	-0.5014
34	3.2700	2.6800	2.2300	.7361	.1223	-0.5817
35	3.4800	2.6000	2.3200	.7454	.0027	-0.6647
36	[illegible].7000	2.5000	2.4300	.7587	-0.1263	-0.7421
37	3.9200	2.3700	2.5500	.7793	-0.2686	-0.8129
38	4.1200	2.4600	2.6300	.7947	-0.3096	-0.8232
39	4.3300	2.6400	2.6900	.8084	-0.3199	-0.8163
40	4.5500	2.7900	2.7680	.8220	-0.3442	-0.8176
41	4.7500	2.8600	3.0200	.7958	-0.3046	-0.8192
42	4.9300	2.9200	3.2600	.7712	-0.2706	-0.8215
43	5.1300	3.0000	3.3400	.7850	-0.3075	-0.8309
44	5.3200	3.1800	3.3500	.8037	-0.3270	-0.8252
45	5.5000	3.2400	3.6000	.7797	-0.2912	-0.8261
46	5.6700	3.3200	3.8300	.7571	-0.2539	-0.8242
47	5.8300	3.4100	3.9800	.7[illegible]89	-0.2402	-0.8232
48	5.9800	3.4800	4.1900	.7284	-0.2090	-0.8223
49	6.1300	3.5900	4.1400	.7572	-0.2540	-0.8241
50	6.2700	3.6900	4.1900	.7644	-0.2633	-0.8232
51	6.4200	3.8200	4.0800	.798[illegible]	-0.3201	-0.8260
52	6.5500	3.9100	4.1800	.7950	-0.3103	-0.8234
53	6.7000	4.0100	4.2700	.7953	-0.3089	-0.8222
54	6.8000	4.0700	4.3100	.7990	-0.3164	-0.8232
55	6.9200	4.1400	4.3700	.8016	-0.3220	-0.8241
56	7.0300	4.2100	4.4200	.8043	-0.3267	-0.8244
57	7.1500	4.2800	4.4700	.8081	-0.3351	-0.8258
58	7.2700	4.3600	4.5100	.8127	-0.3434	-0.8263
59	7.3700	4.4200	4.5400	.8172	-0.3530	-0.8277
60	7.4700	4.48[illegible]	4.5900	.8188	-0.3565	-0.8283

TABLE 14.8 (Cont'd)

ALTI-TUDE	COEFFICIENTS OF VARIATION			CORRELATION COEFFICIENTS		
(km)	$\sigma(\rho)/\bar{\rho}$ (percent)	$\sigma(P)/\bar{P}$ (percent)	$\sigma(T)/\bar{T}$ (percent)	$r(P\rho)$ (unitless)	$r(PT)$ (unitless)	$r(\rho T)$ (unitless)
61	7.5700	4.5400	4.6300	.8217	-0.3629	-0.8293
62	7.6500	4.7000	4.8600	.7926	-0.2805	-0.8076
63	7.7500	4.9000	5.0000	.7778	-0.2256	-0.7878
64	7.8300	5.1500	5.1500	.7602	-0.1558	-0.7602
65	7.9000	5.3800	5.3800	.7342	-0.0781	-0.7342
66	7.9800	5.5700	5.4400	.7324	-0.0505	-0.7170
67	8.0300	5.6600	5.4700	.7326	-0.0408	-0.7099
68	8.0700	5.7700	5.4000	.7437	-0.0429	-0.6998
69	8.1000	5.8200	5.5100	.7331	-0.0215	-0.6957
70	8.1200	5.8700	5.4900	.7369	-0.0208	-0.6911
71	8.1200	5.8900	5.4700	.7392	-0.0205	-0.6885
72	8.0700	5.7900	5.3800	.7459	-0.0426	-0.6973
73	8.1200	5.6500	5.2900	.7615	-0.1008	-0.7216
74	8.0700	5.5000	5.1700	.7733	-0.1432	-0.7383
75	7.9000	5.2900	5.4100	.7313	-0.0901	-0.7452
76	7.6800	4.9100	5.6500	.6779	-0.0383	-0.7606
77	7.3800	5.0100	6.1600	.5628	.1390	-0.7403
78	7.0500	5.0400	6.5200	.4587	.2771	-0.7267
79	6.6800	5.1100	6.8400	.3508	.4045	-0.7145
80	6.3200	5.2700	6.7800	.3265	.4730	-0.6784
81	5.9500	5.3600	6.7200	.2975	.5342	-0.6482
82	5.5800	5.5200	6.6600	.2800	.5942	-0.6057
83	5.2500	5.1300	6.6100	.1891	.6259	-0.6475
84	4.9200	4.7800	6.5600	.0855	.6645	-0.6877
85	4.6300	4.4700	6.5100	-0.0232	.7032	-0.7272
86	4.4000	4.1900	6.4500	-0.1271	.7363	-0.7647
87	4.2000	3.9600	6.4000	-0.2296	.7694	-0.7983
88	4.0200	4.0500	6.3400	-0.2344	.7874	-0.7838
89	3.8800	4.1400	6.2800	-0.2255	.7986	-0.7665
90	3.7800	4.0400	5.9600	-0.1608	.7798	-0.7432
91	3.6800	3.9100	5.6500	-0.1074	.7620	-0.7257
92	3.4900	3.7500	5.2300	-0.0424	.7453	-0.6977
93	3.5200	2.7500	5.0300	-0.2762	.7400	-0.8508
94	3.5600	2.6800	4.7900	-0.1618	.6798	-0.8338
95	3.5900	2.6100	4.5300	-0.0438	.6109	-0.8177
96	3.6300	2.5500	4.3700	.0315	.5574	-0.8123
97	3.6600	2.5700	4.3400	.0619	.5399	-0.8066
98	3.7000	2.5200	4.3300	.0693	.5228	-0.8142
99	3.7300	3.6000	4.1500	.3593	.5445	-0.5871
100	3.7700	3.6800	4.1600	.3766	.5433	-0.5731
101	3.8000	3.7700	4.1800	.3902	.5472	-0.5571
102	3.8300	3.9100	4.2200	.4056	.5584	-0.5318
103	3.8700	4.1000	4.2900	.4217	.5753	-0.4991
104	3.9000	4.2200	4.3200	.4361	.5831	-0.4767
105	3.9400	4.3500	4.3600	.4503	.5908	-0.4544
106	3.9700	4.6100	4.5700	.4406	.6260	-0.4242
107	4.0000	4.8200	4.7300	.4372	.6493	-0.4001
108	4.0400	5.0500	4.9300	.4294	.6725	-0.3797
109	4.0800	5.1400	5.0200	.4260	.6777	-0.3766
110	4.1200	5.1300	5.0500	.4208	.6725	-0.3883
111	4.1600	5.1000	5.0700	.4150	.6654	-0.4030
112	4.1900	5.0800	5.0900	.4100	.6605	-0.4140
113	4.2300	5.0700	5.1200	.4053	.6554	-0.4248
114	4.2700	5.0500	5.1500	.3991	.6497	-0.4378
115	4.3000	5.0700	5.1900	.3958	.6489	-0.4418
116	4.3300	4.9900	5.1700	.3915	.6373	-0.4596
117	4.3600	5.0200	5.2300	.3851	.6388	-0.4640
118	4.3900	4.9700	5.2300	.3899	.6306	-0.4774
119	4.4200	5.0300	5.3100	.3743	.6357	-0.4779
120	4.4600	5.0600	5.3700	.3691	.6357	-0.4828

The required values for pressure and temperature are the last two terms multiplied by $\overline{P}$ and $\overline{T}$, respectively, obtaining the appropriate values from Table 14.8.

In general the equations of interest are

$$(\overline{\rho} \pm M\sigma_{\rho}) = \overline{\rho}\left[1 \pm M\left(\frac{\sigma_{\rho}}{\overline{\rho}}\right)\right]$$

$$= \overline{\rho}\left[1 \pm M\left\{\left(\frac{\sigma_P}{\overline{P}}\right) r(PT)\; r(\rho T) - \left(\frac{\sigma_T}{\overline{T}}\right) r(\rho T)\right\}\right] \qquad (14.7a)$$

$$(\overline{P} \pm M\sigma_P) = \overline{P}\left[1 \pm M\left(\frac{\sigma_P}{\overline{P}}\right)\right]$$

$$= \overline{P}\left[1 \pm M\left\{\left(\frac{\sigma_{\rho}}{\overline{\rho}}\right) r(P\rho) + \left(\frac{\sigma_T}{\overline{T}}\right) r(PT)\right\}\right] \qquad (14.7b)$$

$$(\overline{T} \pm M\sigma_T) = \overline{T}\left[1 \pm M\left(\frac{\sigma_{\rho}}{\overline{\rho}}\right)\right]$$

$$= \overline{T}\left[1 \pm M\left\{\left(\frac{\sigma_P}{\overline{P}}\right) r(P\rho)\; r(\rho T) - \left(\frac{\sigma_{\rho}}{\overline{\rho}}\right) r(\rho T)\right\}\right]. \qquad (14.7c)$$

where the "M" denotes the multiplication factor to give the desired deviation. The values of M for the normal distribution and the associated percentile levels are as follows:

	M		Percentile
mean	-3	standard deviations	0.135
mean	-2	standard deviations	2.275
mean	-1	standard deviations	15.866
mean	±0	standard deviations = median	50.000
mean	+1	standard deviations	84.134
mean	+2	standard deviations	97.725
mean	+3	standard deviations	99.865

14.6 Extreme Density Profiles

The envelopes of deviations of density given in Table 14.7 imply that individual extreme density profiles may be represented by similarly shaped profiles, i.e. all negative or all positive deviations of density from sea level to 120 km altitude. When many individual density profiles are examined, it is evident that when large positive deviations of density occur at the surface there will be correspondingly large negative diviations near 15 km altitude. The reverse is also true, that density profiles with negative deviations at lower levels have corresponding positive deviations at higher levels. An envelope of extremes taken at discrete altitudes is not an extreme profile.

An effort is in progress to produce typical profiles for temperature, pressure, and density characteristic of extremals for selected atmospheres.

14.7 Reference Atmospheres

In design and preflight analysis of space vehicles, special atmospheres are used to represent the mean or median thermodynamic conditions with respect to altitude. For general world wide design, the U. S. Standard Atmosphere, 1962 (Ref. 14.2) is used, but more specific atmospheres are needed at each launch area. A group of Range Reference Atmospheres (Ref. 14.4) have been prepared to represent the thermodynamic medians in the first 30 km at various launch areas.

A more extensive reference atmosphere presenting data to 700 km has been published for the Eastern Test Range as NASA TM X-53139, "A Reference Atmosphere for Patrick AFB, Florida, Annual (1963 Revision)," (Ref. 14.1). Because of the utility of this atmosphere, the table from the referenced report is included in this section as Table 14.9. The computer subroutine used to prepare the tables in this section is available in the subroutine files of the George C. Marshall Space Flight Center Computation Laboratory, Huntsville, Alabama, as Computer Subroutine PRA-63.

In Table 14.9, the tabular values are given in standard computer printout where the two-digit numbers which are at the end of the tabular value (number preceeded by E) indicate the power of 10 by which the respective principal value must be multiplied. For example, a tabular value indicated as

2.9937265E 02 is 299.37265

or

1.5464054E-05 is 0.000015464054.

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9

GEOMETRIC ALTITUDE	PRESSURE	KINETIC TEMPERATURE	VIRTUAL TEMPERATURE	DENSITY	KINEMATIC VISCOSITY	COEFFICIENT OF VISCOSITY	SPEED OF SOUND
meters	newtons cm^{-2}	degrees K	degrees K	kg m^{-3}	m^2 sec^{-1}	newton-sec m^{-2}	m sec^{-1}
-0.	1.0170147E 01	2.9667877E 02	2.9937265E 02	1.1835467E 00	1.5464054E-05	1.8302431E-05	3.4685752E 02
250.	9.8829373E 00	2.9503576E 02	2.9749989E 02	1.1573534E 00	1.5746406E-05	1.8224157E-05	3.4577091E 02
500.	9.6022651E 00	2.9348321E 02	2.9573026E 02	1.1312045E 00	1.6044844E-05	1.8149999E-05	3.4474100E 02
750.	9.3280864E 00	2.9200674E 02	2.9404920E 02	1.1051789E 00	1.6358708E-05	1.8079299E-05	3.4375977E 02
1000.	9.0603418E 00	2.9059301E 02	2.9244316E 02	1.0793462E 00	1.6687362E-05	1.8011441E-05	3.4281972E 02
1250.	8.7989596E 00	2.8922965E 02	2.9089953E 02	1.0537666E 00	1.7030194E-05	1.7945850E-05	3.4191375E 02
1500.	8.5438573E 00	2.8790525E 02	2.8940665E 02	1.0284922E 00	1.7386608E-05	1.7881991E-05	3.4103527E 02
1750.	8.2949430E 00	2.8660932E 02	2.8795373E 02	1.0035670E 00	1.7756031E-05	1.7819367E-05	3.4017814E 02
2000.	8.0521168E 00	2.8533228E 02	2.8653088E 02	9.7902801E-01	1.8137912E-05	1.7757524E-05	3.3933664E 02
2250.	7.8152728E 00	2.8406543E 02	2.8512905E 02	9.5490568E-01	1.8531717E-05	1.7696042E-05	3.3850555E 02
2500.	7.5843002E 00	2.8280087E 02	2.8374002E 02	9.3122447E-01	1.8936939E-05	1.7634541E-05	3.3768001E 02
2750.	7.3590840E 00	2.8153156E 02	2.8235634E 02	9.0800345E-01	1.9353094E-05	1.7572676E-05	3.3685564E 02
3000.	7.1395065E 00	2.8025121E 02	2.8097134E 02	8.8525681E-01	1.9779728E-05	1.7510139E-05	3.3602846E 02
3250.	6.9254477E 00	2.7895429E 02	2.7957909E 02	8.6293447E-01	2.0216413E-05	1.7446653E-05	3.3519489E 02
3500.	6.7167869E 00	2.7763601E 02	2.7817435E 02	8.4122243E-01	2.0662760E-05	1.7381977E-05	3.3435175E 02
3750.	6.5134029E 00	2.7629224E 02	2.7675260E 02	8.1994327E-01	2.1118413E-05	1.7315901E-05	3.3349622E 02
4000.	6.3151745E 00	2.7491954E 02	2.7530995E 02	7.9915662E-01	2.1583059E-05	1.7248245E-05	3.3262585E 02
4250.	6.1219816E 00	2.7351511E 02	2.7384314E 02	7.7885945E-01	2.2056429E-05	1.7178858E-05	3.3173858E 02
4500.	5.9337050E 00	2.7207674E 02	2.7234951E 02	7.5904647E-01	2.2538305E-05	1.7107621E-05	3.3083264E 02
4750.	5.7502279E 00	2.7060280E 02	2.7082700E 02	7.3971052E-01	2.3028518E-05	1.7034437E-05	3.2990662E 02
5000.	5.5714348E 00	2.6909222E 02	2.6927405E 02	7.2084275E-01	2.3526960E-05	1.6959239E-05	3.2895940E 02
5250.	5.3972132E 00	2.675[illegible]E 02	2.6768968E 02	7.0243297E-01	2.4033585E-05	1.6881983E-05	3.2799020E 02
5500.	5.2274531E 00	2.6[illegible] 02	2.6607333E 02	6.8446986E-01	2.4548412E-05	1.6802648E-05	3.2699847E 02
5750.	5.0620471E 00	2.64[illegible]E 02	2.6442497E 02	6.6694129E-01	2.5071532E-05	1.6721240E-05	3.2598400E 02
6000.	4.9008912E 00	2.6267950E 02	2.6274496E 02	6.4983435E-01	2.5603110E-05	1.6637781E-05	3.2494679E 02
6250.	4.7438843E 00	2.6098670E 02	2.6103417E 02	6.3313566E-01	2.6143393E-05	1.6552315E-05	3.2388713E 02
6500.	4.5909286E 00	2.5926069E 02	2.5929361E 02	6.1683158E-01	2.6692708E-05	1.6464906E-05	3.2280552E 02
6750.	4.4419296E 00	2.5750339E 02	2.5752496E 02	6.0090817E-01	2.7251477E-05	1.6375635E-05	3.2170270E 02
7000.	4.2967959E 00	2.5571708E 02	2.5573002E 02	5.8535153E-01	2.7820208E-05	1.6284601E-05	3.2057962E 02
7250.	4.1554397E 00	2.5390429E 02	2.5391096E 02	5.7014776E-01	2.8399511E-05	1.6191918E-05	3.1943741E 02
7500.	4.0177761E 00	2.5206783E 02	2.5207021E 02	5.5528319E-01	2.8990096E-05	1.6097713E-05	3.1827741E 02
7750.	3.8837237E 00	2.5021074E 02	2.5021046E 02	5.4074435E-01	2.9592781E-05	1.6002129E-05	3.1710117E 02
8000.	3.7532040E 00	2.4833622E 02	2.4833459E 02	5.2651817E-01	3.0208491E-05	1.5905319E-05	3.1591021E 02
8250.	3.6261415E 00	2.4644770E 02	2.4644571E 02	5.1259196E-01	3.0838268E-05	1.5807448E-05	3.1470648E 02
8500.	3.5024639E 00	2.4454868E 02	2.4454707E 02	4.9895351E-01	3.1483272E-05	1.5708689E-05	3.1349187E 02
8750.	3.3821013E 00	2.4264284E 02	2.4264207E 02	4.8559116E-01	3.2144787E-05	1.5609225E-05	3.1226845E 02
9000.	3.2649869E 00	2.4073389E 02	2.4073420E 02	4.7249382E-01	[illegible].2824226E-05	1.5509244E-05	3.1103836E 02
9250.	3.1510561E 00	2.3882567E 02	2.3882706E 02	4.5965099E-01	3.3523131E-05	1.5408941E-05	3.0980386E 02
9500.	3.0402469E 00	2.3692182E 02	2.3692429E 02	4.4705284E-01	3.4243187E-05	1.5308514E-05	3.0856726E 02
9750.	2.9324993E 00	2.3502631E 02	2.3502955E 02	4.3469020E-01	3.4986216E-05	1.5208165E-05	3.0733094E 02
10000.	2.8277555E 00	2.3314283E 02	2.3314652E 02	4.2255460E-01	3.5754185E-05	1.5108096E-05	3.0609732E 02
10250.	2.7259597E 00	2.3127509E 02	2.3127885E 02	4.1063824E-01	3.6549218E-05	1.5008507E-05	3.0466882E 02
10500.	2.6270579E 00	2.2942670E 02	2.2943012E 02	3.9893405E-01	3.7373593E-05	1.4909599E-05	3.0364789E 02
10750.	2.5309974E 00	2.2760114E 02	2.2760385E 02	3.[illegible]743564E-01	3.8229747E-05	1.4811567E-05	3.0243695E 02
11000.	2.4373144E 00	2.2567654E 02	2.2567654E 02	3.7638429E-01	3.9076662E-05	1.4707842E-05	3.0115374E 02
11250.	2.3466644E 00	2.2389290E 02	2.2389290E 02	3.[illegible]528[illegible]88E-01	3.9999485E-05	1.4611367E-05	2.9996129E 02
11500.	2.2587459E 00	2.2215274E 02	2.2215274E 02	3.5436502E-01	4.0966008E-05	1.4516921E-05	2.9879332E 02
11750.	2.1735153E 00	2.2046105E 02	2.2046105E 02	3.4360979E-01	4.1980165E-05	1.4424796E-05	2.9765349E 02
12000.	2.0909281E 00	2.1882266E 02	2.1882266E 02	3.3302120E-01	4.3046155E-05	1.4335282E-05	2.9654540E 02
12250.	2.0109393E 00	2.1724226E 02	2.1724226E 02	3.2259810E-01	4.4168460E-05	1.4248661E-05	2.9547260E 02
12500.	1.9335036E 00	2.1572436E 02	2.1572436E 02	3.1234019E-01	4.5351869E-05	1.4165211E-05	2.9443853E 02
12750.	1.8585748E 00	2.1427329E 02	2.1427329E 02	3.0224786E-01	4.6601486E-05	1.4085200E-05	2.9344659E 02
13000.	1.786106[illegible]	2.1289318E 02	2.1289318E 02	2.9232218E-01	4.7922760E-05	1.4008886E-05	2.9250004E 02
13250.	1.71605[illegible]	2.1158795E 02	2.1158795E 02	2.8256482E-01	4.9321493E-05	1.3936519E-05	2.9160202E 02
13500.	1.64836[illegible]	2.1036130E 02	2.1036130E 02	2.7297794E-01	5.0803867E-05	1.3868335E-05	2.9075553E 02
13750.	1.5829980E 00	2.0921670E 02	2.0921670E 02	2.6356414E-01	5.2376472E-05	1.3804560E-05	2.8996343E 02
14000.	1.5199026E 00	2.0815732E 02	2.0815732E 02	2.5432637E-01	5.4046313E-05	1.3745403E-05	2.8922838E 02
14250.	1.4590316E 00	2.0718613E 02	2.0718613E 02	2.4526789E-01	5.5820832E-05	1.3691058E-05	2.8855287E 02
14500.	1.4003371E 00	2.0630579E 02	2.0630579E 02	2.3639213E-01	5.7707945E-05	1.3641704E-05	2.8793917E 02
14750.	1.3437711E 00	2.0551865E 02	2.0551865E 02	2.2770271E-01	5.9716027E-05	1.3597501E-05	2.8738935E 02
15000.	1.2892856E 00	2.0482679E 02	2.0482679E 02	2.1920326E-01	6.1853961E-05	1.3558590E-05	2.8690521E 02
15250.	1.2368322E 00	2.0423197E 02	2.0423197E 02	2.1089744E-01	6.4131138E-05	1.3525093E-05	2.8648832E 02
15500.	1.1863629E 00	2.0373557E 02	2.0373557E 02	2.0278882E-01	6.6557450E-05	1.3497107E-05	2.8613994E 02
15750.	1.1378295E 00	2.0333869E 02	2.0333869E 02	1.9488087E-01	6.9143324E-05	1.3474711E-05	2.8586110E 02
16000.	1.0911841E 00	2.0304201E 02	2.0304201E 02	1.[illegible]7685E-01	7.1899693E-05	1.3457958E-05	2.8565248E 02
16250.	1.0463788E 00	2.0284589E 02	2.0284589E 02	1.7967978E-01	7.4838014E-05	1.3446878E-05	2.8551449E 02
16500.	1.0033656E 00	2.0275027E 02	2.0275027E 02	1.7239240E-01	7.7970223E-05	1.3441474E-05	2.8544719E 02
16750.	9.6209732E-01	2.0275470E 02	2.0275470E 02	1.6531714E-01	8.1308715E-05	1.3441724E-05	2.8545030E 02
17000.	9.2252642E-01	2.0285831E 02	2.0285831E 02	1.5845601E-01	8.4866322E-05	1.3447579E-05	2.8552323E 02
17250.	8.8460606E-01	2.0305981E 02	2.0305981E 02	1.5181071E-01	8.8656214E-05	1.3458963E-05	2.8566500E 02
17500.	8.4828967E-01	2.0335748E 02	2.0335748E 02	1.4538244E-01	9.2691882E-05	1.3475772E-05	2.8587431E 02
17750.	8.1353123E-01	2.0374913E 02	2.0374913E 02	1.3917203E-01	9.6986954E-05	1.3497872E-05	2.8614946E 02

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9

GEOMETRIC ALTITUDE	PRESSURE RATIO	DENSITY RATIO	VISCOSITY RATIO	MOLECULAR WEIGHT	PRESSURE DIFFERENCE
meters	unitless	unitless	unitless	unitless	newtons cm^{-2}
-0.	9.9999996E-01	9.9999995E-01	1.0000000E 00	2.8964400E 01	2.3841858E-07
250.	9.7175951E-01	9.7786878E-01	9.9572337E-01	MOLECULAR WEIGHT CONSTANT TO 90,000 METERS	2.8720987E-01
500.	9.4416186E-01	9.5577506E-01	9.9167156E-01		5.6788206E-01
750.	9.1720269E-01	9.3378559E-01	9.8780868E-01		8.4206080E-01
1000.	8.9087617E-01	9.1195906E-01	9.8410108E-01		1.1098053E 00
1250.	8.6517525E-01	8.9034644E-01	9.8051734E-01		1.3711876E 00
1500.	8.4009180E-01	8.6899160E-01	9.7702823E-01		1.6262898E 00
1750.	8.1561680E-01	8.4793186E-01	9.7360662E-01		1.8752042E 00
2000.	7.9174043E-01	8.2719843E-01	9.7022765E-01		2.1180304E 00
2250.	7.6845227E-01	8.0681703E-01	9.6686846E-01		2.3548744E 00
2500.	7.4574143E-01	7.8680835E-01	9.6350816E-01		2.5858470E 00
2750.	7.2359660E-01	7.6718850E-01	9.6012805E-01		2.8110632E 00
3000.	7.0200620E-01	7.4796946E-01	9.5671116E-01		3.0306407E 00
3250.	6.8095845E-01	7.2915960E-01	9.5324244E-01		3.2446995E 00
3500.	6.6044146E-01	7.1076401E-01	9.4970870E-01		3.4533603E 00
3750.	6.4044333E-01	6.9278488E-01	9.4609845E-01		3.6567443E 00
4000.	6.2095212E-01	6.7522185E-01	9.4240189E-01		3.8549727E 00
4250.	6.0195604E-01	6.5807240E-01	9.3861079E-01		4.0481656E 00
4500.	5.8344336E-01	6.4133206E-01	9.3471855E-01		4.2364422E 00
4750.	5.6540262E-01	6.2499476E-01	9.3071997E-01		4.4199193E 00
5000.	5.4782243E-01	6.0905305E-01	9.2661133E-01		4.5987124E 00
5250.	5.3069175E-01	5.9349830E-01	9.2239023E-01		4.7729340E 00
5500.	5.1399974E-01	5.7832093E-01	9.1805561E 01		4.9426941E 00
5750.	4.9773586E-01	5.6351072E-01	9.1360767E-01		5.1081001E 00
6000.	4.8188989E-01	5.4905677E-01	9.0904764E-01		5.2692560E 00
6250.	4.6645187E-01	5.3494775E-01	9.0437800E-01		5.4262629E 00
6500.	4.5141221E-01	5.2117212E-01	8.9960216E-01		5.5792186E 00
6750.	4.3676159E-01	5.0771[illegible]16E-01	8.9472464E-01		5.7282175E 00
7000	4.2249102E-01	4.9457407E-01	8.8975078E-01		5.8733513E 00
7250.	4.0859190E-01	4.8172814E-01	8.8468679E-01		6.0147074E 00
7500.	3.9505585E-01	4.6916878E-01	8.7953967E-01		6.1523710E 00
7750.	3.8187487E-01	4.5688466E-01	8.7431720E-01		6.2864235E 00
8000.	3.6904126E-01	4.4486470E-01	8.6902775E-01		6.4169432E 00
8250.	3.5654760E-01	4.3309820E-01	8.6368030E-01		6.5440056E 00
8500.	3.4438[illegible]74E-01	4.2157483E-01	8.5828435E-01		6.6676832E 00
8750.	3.3255185E-01	4.1028473E-01	8.5284985E-01		6.7880459E 00
9000.	3.2103635E-01	3.9921856E-01	8.4738715E-01		6.9051602E 00
9250.	3.0983387E-01	3.8836742E-01	8.4190682E-01		7.0190911E 00
9500.	2.9893833E-01	3.7772301E-01	8.3641976E-01		7.1299003E 00
9750.	2.8834383E-01	3.6727760E-01	8.3093694E-01		7.2376479E 00
10000.	2.7804469E-01	3.5702401E-01	8.2546939E-01		7.3423917E 00
10250.	2.6803542E-01	3.4695566E-01	8.2002810E-01		7.4441875E 00
10500.	2.5831070E-01	3.3706658E-01	8.1462401E-01		7.5430893E 00
10750.	2.4886536E-01	3.2735136E-01	8.0926777E-01		7.6391498E 00
11000.	2.3965380E-01	3.1801388E-01	8.0360048E-01		7.7328327E 00
11250.	2.3074045E-01	3.0863917E-01	7.9832937E-01		7.8234828E 00
11500.	2.2209570E-01	2.9940940E-01	7.9316903E-01		7.9114012E 00
11750.	2.1371522E-01	2.9032211E-01	7.8813556E-01		7.9966319E 00
12000.	2.0559467E-01	2.8137562E-01	7.8324474E-01		8.0792190E 00
12250.	1.9772962E-01	2.7256896E-01	7.7851201E-01		8.1592078E 00
12500.	1.9011559E-01	2.6390186E-01	7.7395250E-01		8.2366436E 00
12750.	1.8274807E-01	2.5537447E-01	7.6958085E-01		8.3115723E 00
13000.	1.7562250E-01	2.4698829E-01	7.6541126E-01		8.3840404E 00
13250.	1.6873430E-01	2.3874412E-01	7.6145730E-01		8.4540944E 00
13500.	1.6207882E-01	2.3064399E-01	7.5773191E-01		8.5217816E 00
13750.	1.5565143E-01	2.2269010E-01	7.5424739E-01		8.5871491E 00
14000.	1.4944745E-01	2.1488494E-01	7.5101517E-01		8.6502445E 00
14250.	1.4346219E-01	2.0723127E-01	7.48045[illegible]1E-01		8.7111155E 00
14500.	1.3769094E-01	1.9973198E-01	7.4534935E-01		8.7698100E 00
14750.	1.3212898E-01	1.9239013E-01	7.4293422E-01		8.8263760E 00
15000.	1.2677157E-01	1.8520879E-01	7.4080821E-01		8.8808615E 00
15250.	1.2161399E-01	1.7819105E-01	7.3897798E-01		8.9333149E 00
15500.	1.1665149E-01	1.7133994E-01	7.3744892E-01		8.9837942E 00
15750.	1.1187936E-01	1.6455836E-01	7.3622527E-01		9.0323176E 00
16000.	1.0729285E-01	1.5814910E-01	7.3530992E-01		9.0789630E 00
16250.	1.0288728E-01	1.5181469E-01	7.3470452E-01		9.1237683E 00
16500.	9.8657924E-02	1.4565745E-01	7.3440926E-01		9.1667815E 00
16750.	9.4600136E-02	1.3967943E-01	7.3442291E-01		9.2080498E 00
17000.	9.0709249E-02	1.3388234E-01	7.3474283E-01		9.2476207E 00
17250.	8.6980654E-02	1.2826761E-01	7.3536484E-01		9.2855411E 00
17500.	8.3409772E-02	1.2283625E-01	7.3628323E-01		9.3218575E 00
17750.	7.9992077E-02	1.1758896E-01	7.3749069E-01	2.8964400E 01	9.3566159E 00

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE	PRESSURE	KINETIC TEMPERATURE	VIRTUAL TEMPERATURE	DENSITY	KINEMATIC VISCOSITY	COEFFICIENT OF VISCOSITY	SPEED OF SOUND
meters	newtons cm^{-2}	degrees K	degrees K	kg m^{-3}	m^2 sec^{-1}	newton-sec m^{-2}	m sec^{-1}
18000.	7.8097365E-01	2.0530313E 02	2.0530313E 02	1.3239218E-01	1.0261471E-04	1.3585386E-05	2.8723862E 02
18250.	7.4940996E-01	2.0591008E 02	2.0591008E 02	1.2665197E-01	1.0753477E-04	1.3619491E-05	2.8766290E 02
18500.	7.1920003E-01	2.0652754E 02	2.0652754E 02	1.2117497E-01	1.1268123E-04	1.3654144E-05	2.8809388E 02
18750.	6.9028297E-01	2.0715365E 02	2.0715365E 02	1.1594899E-01	1.1806259E-04	1.3689238E-05	2.8853025E 02
19000.	6.6260092E-01	2.0778667E 02	2.0778667E 02	1.1096236E-01	1.2368766E-04	1.3724675E-05	2.8897076E 02
19250.	6.3609868E-01	2.0842488E 02	2.0842488E 02	1.0620395E-01	1.2956538E-04	1.3760356E-05	2.8941420E 02
19500.	6.1072356E-01	2.0906669E 02	2.0906669E 02	1.0166309E-01	1.3570500E-04	1.3796191E-05	2.8985945E 02
19750.	5.8642544E-01	2.0971051E 02	2.0971051E 02	9.7329618E-02	1.4211596E-04	1.3832092E-05	2.9030542E 02
20000.	5.6315652E-01	2.1035486E 02	2.1035486E 02	9.3193799E-02	1.4880793E-04	1.3867977E-05	2.9075100E 02
20250.	5.4087104E-01	2.1099834E 02	2.1099834E 02	8.9246357E-02	1.5579085E-04	1.3903766E-05	2.9119544E 02
20500.	5.1952558E-01	2.1163959E 02	2.1163959E 02	8.5478435E-02	1.6307487E-04	1.3939385E-05	2.9163759E 02
20750.	4.9907848E-01	2.1227735E 02	2.1227735E 02	8.1881557E-02	1.7067049E-04	1.3974765E-05	2.9207668E 02
21000.	4.7949016E-01	2.1291042E 02	2.1291042E 02	7.8447674E-02	1.7858834E-04	1.4009840E-05	2.9251188E 02
21250.	4.6072266E-01	2.1353768E 02	2.1353768E 02	7.5169075E-02	1.8683947E-04	1.4044550E-05	2.9294246E 02
21500.	4.4273989E-01	2.1415808E 02	2.1415808E 02	7.2038414E-02	1.9543514E-04	1.4078838E-05	2.9336769E 02
21750.	4.2550730E-01	2.1477067E 02	2.1477067E 02	6.9048699E-02	2.0438693E-04	1.4112651E-05	2.9378698E 02
22000.	4.0899191E-01	2.1537455E 02	2.1537455E 02	6.6193250E-02	2.1370675E-04	1.4145944E-05	2.9419972E 02
22250.	3.9316222E-01	2.1596891E 02	2.1596891E 02	6.3465692E-02	2.2340689E-04	1.4178673E-05	2.[illegible]460538E 02
22500.	3.7798811E-01	2.1655302E 02	2.1655302E 02	6.0859976E-02	2.3349993E-04	1.4210800E-05	2.[illegible]500350E 02
22750.	3.6344091E-01	2.1712624E 02	2.1712624E 02	5.8370312E-02	2.4399890E-04	1.4242292E-05	2.[illegible]539368E 02
23000.	3.4949304E-01	2.1768800E 02	2.1768800E 02	5.5991186E-02	2.5491726E-04	1.4273120E-05	2.9577557E 02
23250.	3.3611832E-01	2.1823781E 02	2.1823781E 02	5.3717368E-02	2.6626877E-04	1.4303258E-05	2.9614885E 02
23500.	3.2329168E-01	2.1877527E 02	2.1877527E 02	5.1543851E-02	2.7806785E-04	1.4332688E-05	2.9651329E 02
23750.	3.1098904E-01	2.1930008E 02	2.1930008E 02	4.9465870E-02	2.9032938E-04	1.4361396E-05	2.9686872E 02
24000.	2.9918759E-01	2.1981200E 02	2.1981200E 02	4.7478898E-02	3.0306874E-04	1.4389370E-05	2.9721502E 02
24250.	2.8786539E-01	2.2031091E 02	2.2031091E 02	4.5578615E-02	3.1630195E-04	1.4416605E-05	2.9755212E 02
24500.	2.7700151E-01	2.2079671E 02	2.2079671E 02	4.3760[illegible]15E-02	3.3004554E-04	1.4443099E-05	2.9788000E 02
24750.	2.6657591E-01	2.2126948E 02	2.2126948E 02	4.2021881E-02	3.4431725E-04	1.4468859E-05	2.9819874E 02
25000.	2.5656950E-01	2.2172934E 02	2.2172934E 02	4.0357794E-02	3.5913489E-04	1.4493892E-05	2.9850846E 02
25250.	2.4696393E-01	2.2217648E 02	2.2217648E 02	3.8765104E-02	3.7451754E-04	1.4518211E-05	2.9880929E 02
25500.	2.3774181E-01	2.2261124E 02	2.2261124E 02	3.7240437E-02	3.9048512E-04	1.4541836E-05	2.9910150E 02
25750.	2.2888635E-01	2.2303400E 02	2.2303400E 02	3.5780583E-02	4.0705849E-04	1.4564790E-05	2.9938538E 02
26000.	2.2038159E-01	2.2344526E 02	2.2344526E 02	3.4382489E-02	4.2425962E-04	1.4587102E-05	2.9966127E 02
26250.	2.1221229E-01	2.2384560E 02	2.2384560E 02	3.3043241E-02	4.4211172E-04	1.4608804E-05	2.9992961E 02
26500.	2.0436382E-01	2.2423573E 02	2.2423573E 02	3.1760075E-02	4.6063921E-04	1.4629936E-05	3.0019086E 02
26750.	1.9682221E-01	2.2461640E 02	2.2461640E 02	3.0530360E-02	4.7986792E-04	1.4650541E-05	3.0044556E 02
27000.	1.8957414E-01	2.2498853E 02	2.2498853E 02	2.9351587E-02	4.9982535E-04	1.4670667E-05	3.0069433E 02
27250.	1.8260686E-01	2.2535303E 02	2.2535303E 02	2.8221373E-02	5.2054052E-04	1.4690368E-05	3.0093780E 02
27500.	1.7590816E-01	2.2571105E 02	2.2571105E 02	2.7137454E-02	5.4204438E-04	1.4709705E-05	3.0117577E 02
27750.	1.6946640E-01	2.2606372E 02	2.2606372E 02	2.6097671E-02	5.6436988E-04	1.4728740E-05	3.0141197E 02
28000.	1.6327363E-01	2.2643885E 02	2.2643885E 02	2.5119029E-02	5.8716331E-04	1.4748972E-05	3.0166194E 02
28250.	1.5729220E-01	2.2697720E 02	2.2697720E 02	2.4141415E-02	6.1214233E-04	1.4777987E-05	3.0202032E 02
28500.	1.5154519E-01	2.2751673E 02	2.2751673E 02	2.3204199E-02	6.3811838E-04	1.4807026E-05	3.0237907E 02
28750.	1.4602270E-01	2.2805774E 02	2.2805774E 02	2.2305569E-02	6.6513066E-04	1.4836119E-05	3.0273836E 02
29000.	1.4071528E-01	2.2860044E 02	2.2860044E 02	2.1443810E-02	6.9321970E-04	1.4865272E-05	3.0309836E 02
29250.	1.3561394E-01	2.2914508E 02	2.2914508E 02	2.0617288E-02	7.2242759E-04	1.4894498E-05	3.0345920E 02
29500.	1.3071014E-01	2.2969187E 02	2.2969187E 02	1.9824461E-02	7.5279778E-04	1.4923810E-05	3.0382105E 02
29750.	1.2599566E-01	2.3024104E 02	2.3024104E 02	1.9063850E-02	7.8437554E-04	1.4953217E-05	3.0418403E 02
30000.	1.2146273E-01	2.3079274E 02	2.3079274E 02	1.8334060E-02	8.1720744E-04	1.4982730E-05	3.0454826E 02
30250.	1.1710385E-01	2.3134716E 02	2.3134718E 02	1.7633751E-02	8.5134225E-04	1.5012357E-05	3.0491385E 02
30500.	1.1291193E-01	2.3190450E 02	2.3190450E 02	1.6961662E-02	8.8682977E-04	1.5042107E-05	3.0528090E 02
30750.	1.0888012E-01	2.3246485E 02	2.3246485E 02	1.6316577E-02	9.2372233E-04	1.5071986E-05	3.0564950E 02
31000.	1.0500195E-01	2.3302838E 02	2.3302838E 02	1.5697349E-02	9.6207348E-04	1.5102004E-05	3.0601975E 02
31250.	1.0127118E-01	2.3359519E 02	2.3359519E 02	1.5102878E-02	1.0019389E-03	1.5132162E-05	3.0639170E 02
31500.	9.7681869E-02	2.3416537E 02	2.3416537E 02	1.4532122E-02	1.0433760E-03	1.5162468E-05	3.0676541E 02
31750.	9.4228337E-02	2.3473904E 02	2.3473904E 02	1.3984082E-02	1.0864443E-03	1.5192926E-05	3.0714094E 02
32000.	9.0905080E-02	2.3531626E 02	2.3531626E 02	1.3457797E-02	1.1312058E-03	1.5223539E-05	3.0751834E 02
32250.	8.7706975E-02	2.3589708E 02	2.3589708E 02	1.2952372E-02	1.1777232E-03	1.5254309E-05	3.0789762E 02
32500.	8.4628981E-02	2.3648155E 02	2.3648155E 02	1.2466932E-02	1.2260625E-03	1.5285238E-05	3.0827881E 02
32750.	8.1666349E-02	2.37069[illegible]	2.3706971E 02	1.2000652E-02	1.2762913E-03	1.5316328E-05	3.0866194E 02
33000.	7.8814489E-02	2.3766155E 02	2.3766155E 02	1.1552737E-02	1.3284798E-03	1.5347578E-05	3.0904698E 02
33250.	7.6068993E-02	2.3825710E 02	2.3825710E 02	1.1122427E-02	1.3827008E-03	1.5378989E-05	3.0943396E 02
33500.	7.3425727E-02	2.3885632E 02	2.3885632E 02	1.0709009E-02	1.4390274E-03	1.5410557E-05	3.0982283E 02
33750.	7.0880660E-02	2.3945918E 02	2.3945918E 02	1.0311789E-02	1.4975367E-03	1.5442[illegible]2E-05	3.1021357E 02
34000.	6.8429914E-02	2.4006563E 02	2.4006563E 02	9.9301028E-03	1.5583081E-03	1.5474160E-05	3.1060615E 02
34250.	6.6069812E-02	2.4067563E 02	2.4067563E 02	9.5633199E-03	1.6214230E-03	1.5506187E-05	3.1100052E 02
34500.	6.3796784E-02	2.4128910E 02	2.4128910E 02	9.2108314E-03	1.6869660E-03	1.5538359E-05	3.1139663E 02
34750.	6.1607495E-02	2.4190593E 02	2.4190593E 02	8.8720665E-03	1.7550219E-03	1.5570671E 05	3.1179440E 02
35000.	5.9498639E-02	2.4252600E 02	2.4252600E 02	8.5464640E-03	1.8256808E-03	1.5603116E-05	3.1219375E 02
35250.	5.7467108E-02	2.4314924E 02	2.4314924E 02	8.2334940E-03	1.8990343E-03	1.5635687E-05	3.1259463E 02
35500.	5.5509918E-02	2.4377545E 02	2.4377545E 02	7.9326513E-03	1.9751753E-03	1.5668377E-05	3.1299690E 02
35750.	5.3624192E-02	2.4440454E 02	2.4440454E 02	7.6434468E-03	2.0542013E-03	1.5701179E-05	3.1340050E 02

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE	PRESSURE RATIO	DENSITY RATIO	VISCOSITY RATIO	MOLECULAR WEIGHT	PRESSURE DIFFERENCE
meters	unitless	unitless	unitless	unitless	newtons cm⁻²
18000.	7.6790792E-02	1.1186054E-01	7.4227225E-01	2.8964400E 01	9.3891735E 00
18250.	7.3687228E-02	1.0701054E-01	7.4413570E-01		9.4207371E 00
18500.	7.0716777E-02	1.0238297E-01	7.4602904E-01		9.4509470E 00
18750.	6.7873449E-02	9.7967392E-02	7.4794650E-01		9.4798641E 00
19000.	6.5151556E-02	9.3754101E-02	7.4988266E-01		9.5075462E 00
19250.	6.25[illegible]5671E-02	8.9733[illegible]34E-02	7.5183217E-01		9.5340484E 00
19500.	6.0050611E-02	8.5896982E-02	7.5379012E-01		9.5594236E 00
19750.	5.7661451E-02	8.2235550E-02	7.5575168E-01		9.5837216E 00
20000.	5.5373487E-02	7.8741122E-02	7.5771233E-01		9.6069906E 00
20250.	5.3182223E-02	7.5405859E-02	7.5966776E-01		9.6292760E 00
20500.	5.1063388E-02	7.2222272E-02	7.6161389E-01		9.6506215E 00
20750.	4.9072887E-02	6.9183205E-02	7.6354699E-01		9.6[illegible]1687E 00
21000.	4.7146826E-02	6.6281855E-02	7.6546340E-01		9.6906570E 00
21250.	4.5391473E-02	6.3511706E-02	7.6735986E-01		9.7094245E 00
21500.	4.3533282E-02	6.0866556E-02	7.6923324E-01		9.7274072E 00
21750.	4.1838853E-02	5.8340492E-02	7.7108074E-01		9.7446399E 00
22000.	4.0214945E-02	5.5927871E-02	7.7289979E-01		9.7611552E 00
22250.	3.8658459E-02	5.362330E[illegible]	7.7469801E-01		9.7769849E 00
22500.	3.7166434E-02	5.14216[illegible]	[illegible]44337E-01		9.7921590E 00
2275..	3.5736052E-02	4.9318130E-	[illegible]816400E-01		9.8067062E 00
23000.	3.4364600E-02	4.7307963E-02	7.7984835E-01		9.8206540E 00
23250.	3.3049504E-02	4.5386774E-02	7.81495[illegible]E-01		9.834028[illegible] 00
23500.	3.1788299E-02	4.3550330E-02	7.8310302E-01		9.8468554E 00
23750.	3.0578617E-02	4.1794606E-02	7.8467152E-01		9.8591580E 00
24000.	2.9418216E-02	4.0115778E-02	7.8619996E-01		9.8709595E 00
24250.	2.8304938E-02	3.8510194E-02	7.8768[illegible]2E-01		9.8822818E 00
24500.	2.7236725E-02	3.6974387E-02	7.8913562E-01		9.8931456E 00
24750.	2.6211607E-02	[illegible]5505046E-02	7.9054306E-01	MOLECULAR WEIGHT CONSTANT TO 90,000 METERS	9.9035712E 00
25000.	2.5227707E-02	3.4099028E-02	7.9191080E-01		9.9135777E 00
25250.	2.4283220E-02	3.2753335E-02	7.9323955E-01		9.9231832E 00
25500.	2.3376438E-02	3.1465117E-02	7.9[illegible]53037E-01		9.9324054E 00
25750.	2.2505707E-02	3.0231660E-02	7.9578452E-01		9.9412608E 00
26000.	2.1669459E-02	2.9050386E-02	7.9700357E-01		9.9497656E 00
26250.	2.0866196E-02	2.791883[illegible]E-02	7.9818932E-01		9.9579349E 00
26500.	2.0094489E-02	2.6834661E-02	7.9934393E-01		9.9657834E 00
26750.	1.9352336E-02	2.5795652E-02	8.0046970E-01		9.9733249E 00
27000.	1.8640255E-02	2.4799686E-02	8.0156938E-01		9.9805729E 00
27250.	1.7955183E-02	2.3844747E-02	8.0264578E-01		9.9875402E 00
27500.	1.7296520E-02	2.2928925E-02	8.0370228E-01		9.9942390E 00
27750.	1.6663121E-02	2.2050393E-02	8.0474230E-01		1.0006081E 01
28000.	1.6054205E-02	2.1223521E-02	8.0584776E-01		1.0006873E 01
28250.	1.5466069E-02	2.0397517E-02	8.0743278E-01		1.0012855E 01
28500.	1.4900983E-02	1.9605646E-02	8.0901966E-01		1.0018602E 01
28750.	1.4357973E-02	1.8846378E-02	8.1060922E-01		1.0024124E 01
29000.	1.383[illegible]110E-02	1.8118262E-02	8.1220207E-01		1.0029432E 01
29250.	1.3334511E-02	1.7419919E-02	8.1379834E-01		1.0034533E 01
29500.	1.2852335E-02	1.6750045E-02	8.1540048E-01		1.0039437E 01
29750.	1.2388774E-02	1.6107391E-02	8.1700722E-01		1.0044151E 01
3000..	1.1943065E-02	1.5490778E-02	8.1861973E-01		1.0048684E 01
302[illegible].	1.1514463E-02	1.4899074E-02	8.2023848E-01		1.0053043E 01
30500.	1.1102290E-02	1.4331214E-02	8.[illegible]186393E-01		1.0057235E 0[illegible]
30750.	1.0705855E-02	1.3786170E-02	8.2349647E-01		1.0061267E 01
31000.	1.0324527E-02	1.3262973E-02	8.2513652E-01		1.0065145E 01
31250.	9.9576907E-03	1.2760694E-02	8.2678432E-01		1.0068876E 01
31500.	9.6047645E-03	1.2278452E-02	8.2844017E-01		1.0072465E 01
31750.	9.2651891E-03	1.1815403E-02	8.3010430E-01		1.0075919E 01
32000.	8.9384232E-03	1.1370735E-02	8.3177692E-01		1.0079242E 01
32250.	8.6239631E-03	1.0943693E-02	8.3345811E-01		1.0082440E 01
32500.	8.3213134E-03	1.0533536E-02	8.3514802E-01		1.0085518E 01
32750.	8.0300065E-03	1.0139567E-02	8.3684671E-01		1.0088481E 01
33000.	7.7495918E-03	9.7611161E-03	8.3855411E-01		1.0091332E 01
33250.	7.4796354E-03	9.3975394E-03	8.4027032E-01		1.0094078E 01
33500.	7.2197310E-03	9.0482346E-03	8.4199516E-01		1.0096721E 01
33750.	6.9694821E-03	8.7126163E-03	8.4372852E-01		1.0099266E 01
34000.	6.7285077E-03	8.3901230E-03	8.4547024E-01		1.0101717E 01
34250.	6.4964459E-03	8.0802215E-03	8.4722012E-01		1.0104077E 01
34500.	6.2729460E-03	7.7823977E-03	8.4857795E-01		1.0106350E 01
34750.	6.0576797E-03	7.4961690E-03	8.[illegible]074338E-01		1.0108539E 01
35000.	5.8503222E-03	7.2210616E-03	8.5251606E-01		1.0110648E 01
35250.	5.6505679E-03	6.9566277E-03	8.5429571E-01		1.0112680E 01
35500.	5.4581233E-03	6.7024403E-03	8.5608178E-01		1.0114637E 01
3575[illegible].	5.2727056E-03	6.4580[illegible]62E-03	8.5787399E-01	2.8964400E 01	1.0116523E 01

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE meters	PRESSURE newtons cm⁻²	KINETIC TEMPERATURE degrees K	VIRTUAL TEMPERATURE degrees K	DENSITY kg m⁻³	KINEMATIC VISCOSITY m² sec⁻¹	COEFFICIENT OF VISCOSITY newton-sec m⁻²	SPEED OF SOUND m sec⁻¹
36000.	5.1807184E-02	2.4503628E 02	2.4503628E 02	7.3654170E-03	2.1362103E-03	1.5734080E-05	3.1380529E 02
36250.	5.0056203E-02	2.4567052E 02	2.4567052E 02	7.0981081E-03	2.2213063E-03	1.5767073E-05	3.1421114E 02
36500.	4.8368751E-02	2.4630706E 02	2.4630706E 02	6.8410974E-03	2.3095922E-03	1.5800146E-05	3.1461774E 02
36750.	4.6742370E-02	2.4694566E 02	2.4694566E 02	6.5939717E-03	2.4011762E-03	1.5833288E-05	3.1502553E 02
37000.	4.5174757E-02	2.4758610E 02	2.4758610E 02	6.3563430E-03	2.4961657E-03	1.5866486E-05	3.1543376E 02
37250.	4.3663611E-02	2.4822817E 02	2.4822817E 02	6.1278247E-03	2.5946774E-03	1.5899729E-05	3.1584251E 02
37500.	4.2206814E-02	2.4887154E 02	2.4887154E 02	5.9080626E-03	2.6968231E-03	1.5933000E-05	3.1625156E 02
37750.	4.0802266E-02	2.4951598E 02	2.4951593E 02	5.6967042E-03	2.8027235E-03	1.5966287E-05	3.1666075E 02
38000.	3.9447995E-02	2.5016116E 02	2.5016116E 02	5.4934139E-03	2.9124978E-03	1.5999574E-05	3.1706989E 02
38250.	3.8142081E-02	2.5080680E 02	2.5080680E 02	5.2978887E-03	3.0262704E-03	1.6032844E-05	3.1747875E 02
38500.	3.6882693E-02	2.5145256E 02	2.5145256E 02	5.1098048E-03	3.1441673E-03	1.6066081E-05	3.1788723E 02
38750.	3.5668057E-02	2.5209809E 02	2.5209809E 02	4.9289731E-03	3.2663182E-03	1.6099268E-05	3.1829501E 02
39000.	3.4496486E-02	2.5274305E 02	2.5274305E 02	4.7548124E-03	3.3928543E-03	1.6132386E-05	3.1870190E 02
39250.	3.3366343E-02	2.5338705E 02	2.5338705E 02	4.5873598E-03	3.5239111E-03	1.6165417E-05	3.1910768E 02
39500.	3.2276080E-02	2.5402967E 02	2.5402967E 02	4.4262311E-03	3.6596231E-03	1.6198338E-05	3.1951207E 02
39750.	3.1224165E-02	2.5467056E 02	2.5467056E 02	4.2711993E-03	3.8001346E-03	1.6231132E-05	3.1991487E 02
40000.	3.0209180E-02	2.5530928E 02	2.5530928E 02	4.1220200E-03	3.9455843E-03	1.6263778E-05	3.2031579E 02
40250.	2.9229723E-02	2.5594537E 02	2.5594537E 02	3.9784617E-03	4.0961187E-03	1.6296252E-05	3.2071457E 02
40500.	2.8284457E-02	2.5657837E 02	2.5657837E 02	3.8403036E-03	4.2518854E-03	1.6328531E-05	3.2111092E 02
40750.	2.7372115E-02	2.5720782E 02	2.5720782E 02	3.7073359E-03	4.4130322E-03	1.6360593E-05	3.2150456E 02
41000.	2.6491424E-02	2.5783324E 02	2.5783324E 02	3.5793500E-03	4.5797177E-03	1.6392412E-05	3.2189520E 02
41250.	2.5641234E-02	2.5845410E 02	2.5845410E 02	3.4561553E-03	4.7520914E-03	1.6423966E-05	3.2228253E 02
41500.	2.4820392E-02	2.5906989E 02	2.5906989E 02	3.3375628E-03	4.9303122E-03	1.6455227E-05	3.2266623E 02
41750.	2.4027806E-02	2.5968005E 02	2.5968005E 02	3.2233931E-03	5.1145384E-03	1.6486168E-05	3.2304598E 02
42000.	2.3262411E-02	2.6028407E 02	2.6028407E 02	3.1134715E-03	5.3049350E-03	1.6516764E-05	3.2342147E 02
42250.	2.2523202E-02	2.6088134E 02	2.6088134E 02	3.0076332E-03	5.5016637E-03	1.6546987E-05	3.2379233E 02
42500.	2.1809203E-02	2.6147127E 02	2.6147127E 02	2.9057167E-03	5.7048901E-03	1.6576896E-05	3.2415822E 02
42750.	2.1119469E-02	2.6205329E 02	2.6205329E 02	2.8075735E-03	5.9147853E-03	1.6606195E-05	3.2451880E 02
43000.	2.0453117E-02	2.6262673E 02	2.6262673E 02	2.7130530E-03	6.1315131E-03	1.6635121E-05	3.2487367E 02
43250.	1.9809245E-02	2.6319098E 02	2.6319098E 02	2.6220120E-03	6.3552547E-03	1.6663554E-05	3.2522247E 02
43500.	1.9187063E-02	2.6374536E 02	2.6374536E 02	2.5343198E-03	6.5861708E-03	1.6691463E-05	3.2556482E 02
43750.	1.8585732E-02	2.6428923E 02	2.6428923E 02	2.4498413E-03	6.8244486E-03	1.6718816E-05	3.2590032E 02
44000.	1.8004513E-02	2.6482185E 02	2.6482185E 02	2.3684559E-03	7.0702506E-03	1.6745577E-05	3.2622854E 02
44250.	1.7442635E-02	2.6534256E 02	2.6534256E 02	2.2900392E-03	7.3237678E-03	1.6771716E-05	3.2654911E 02
44500.	1.6899401E-02	2.6585060E 02	2.6585060E 02	2.2144782E 03	7.5851708E-03	1.6797196E-05	3.2686158E 02
44750.	1.6374120E-02	2.6634524E 02	2.6634524E 02	2.1416613E-03	7.8546414E-03	1.6821981E-05	3.2716551E 02
45000.	1.5866134E-02	2.6682574E 02	2.6682574E 02	2.0714819E-03	8.1323606E-03	1.6846038E-05	3.2746049E 02
45250.	1.5374807E-02	2.6729129E 02	2.6729129E 02	2.0038380E-03	8.4185084E-03	1.6869327E-05	3.2774604E 02
45500.	1.4899529E-02	2.6774109E 02	2.6774109E 02	1.9386315E-03	8.7132648E-03	1.6891810E-05	3.2802169. 02
45750.	1.4439711E-02	2.6817436E 02	2.6817436E 02	1.8757674E-03	9.0168161E-03	1.6913450E-05	3.2828639E 02
46000.	1.3994781E-02	2.6859025E 02	2.6859025E 02	1.8151546E-03	9.3293467E-03	1.6934206E-05	3.2854145E 02
46250.	1.3564215E-02	2.6898792E 02	2.6898792E 02	1.7567082E-03	9.6510271E-03	1.6954039E-05	3.2878458E 02
46500.	1.3147466E-02	2.6936653E 02	2.6936653E 02	1.7003415E-03	9.9820579E-03	1.6972909E-05	3.2901589E 02
46750.	1.2744065E-02	2.6972512E 02	2.6972512E 02	1.6459792E-03	1.0322590E-02	1.6990770E-05	3.2923481E 02
47000.	1.2353487E-02	2.7006288E 02	2.7006288E 02	1.5935389E-03	1.0672843E-02	1.7007582E-05	3.2944089E 02
47250.	1.1975290E-02	2.7037884E 02	2.7037884E 02	1.5429473E-03	1.1032976E-02	1.7023301E-05	3.2963355E 02
47500.	1.1609022E-02	2.7067210E 02	2.7067210E 02	1.4941352E-03	1.1403173E-02	1.7037882E-05	3.2981226E 02
47750.	1.1254254E-02	2.7094166E 02	2.7094166E 02	1.4470338E-03	1.1783607E-02	1.7051279E-05	3.2997645E 02
48000.	1.0910568E-02	2.7118660E 02	2.711[illegible] 02	1.401576 E-03	1.2174463E-02	1.7063447E-05	3.3012557E 02
48250.	1.0577570E-02	2.7140590E 02	2.7140590E 02	1.3577018E-03	1.2575910E-02	1.7074335E-05	3.3025902E 02
48500.	1.0254871E-02	2.7159857E 02	2.7159857E 02	1.3153475E-03	1.2988126E-02	1.7083899E-05	3.3037623E 02
48750.	9.9421220E-03	2.7176355E 02	2.7176355E 02	1.2744583E-03	1.3411255E-02	1.7092086E-05	3.3047655E 02
49000.	9.6365027E-03	2.7187674E 02	2.7187674E 02	1.2347674E-03	1.3846901E-02	1.7097701E-05	3.3054537E 02
49250.	9.3444532E-03	2.7158682E 02	2.7158682E 02	1.1986240E-03	1.4252440E-02	1.7083316E-05	3.3036908E 02
49500.	9.0608503E-03	2.7127908E 02	2.7127908E 02	1.1635643E-03	1.4668753E-02	1.7068039E-05	3.3018185E 02
49750.	8.7854533E-03	2.7095394E 02	2.7095394E 02	1.1295526E-03	1.5096144E-02	1.7051889E-05	3.2998393E 02
50000.	8.5180215E-03	2.7061178E 02	2.7061178E 02	1.0965534E-03	1.5534932E-02	1.7034883E-05	3.2977550E 02
50250.	8.2583286E-03	2.7025298E 02	2.7025298E 02	1.0645331E-03	1.5985440E-02	1.7017040E-05	3.2955681E 02
50500.	8.0061513E-03	2.6987793E 02	2.6987793E 02	1.0334612E-03	1.6448006E-02	1.6998377E-05	3.2932805E 02
50750.	7.7612761E-03	2.6948699E 02	2.6948699E 02	1.0033052E-03	1.6922975E-02	1.6978910E-05	3.2908944E 02
51000.	7.5234920E-03	2.6908057E 02	2.6908057E 02	9.7403572E-04	1.7410715E-02	1.6958658E-05	3.2884119E 02
51250.	7.2925984E-03	2.6865905E 02	2.6865905E 02	9.4562420E-04	1.7911596E-02	1.6937638E-05	3.2858353E 02
51500.	7.0683973E-03	2.6822277E 02	2.6822277E 02	9.1804399E-04	1.8426005E-02	1.6915866E-05	3.2831662E 02
51750.	6.8506990E-03	2.6777211E 02	2.6777211E 02	8.9126533E-04	1.8954342E-02	1.6893359E-05	3.2804069E 02
52000.	6.6393177E-03	2.6730745E 02	2.6730745E 02	8.6526743E-04	1.9497023E-02	1.6870136E-05	3.2775595E 02
52250.	6.4340792E-03	2.6682914E 02	2.6682914E 02	8.4002243E-04	2.0054474E-02	1.6846209E-05	3.2746258E 02
52500.	6.2348041E-03	2.6633759E 02	2.6633759E 02	8.1 50777E-04	2.0627146E-02	1.6821598E-05	3.2716081E 02
52750.	6.0413253E-03	2.6583313E 02	2.6583313E 02	7.9170040E-04	2.1215500E-02	1.6796320E-05	3.2685074E 02
53000.	5.8534791E-03	2.6531610E 02	2.6531610E 02	6857846E-04	2.1920008E-02	1.6770388E 05	3.2653283E 02
53250.	5.6711066E-03	[illegible] 02	2.6478688E 02	7.4612072E-04	2.2441168E-02	1.6743821E-05	3.2620700E 02
53500.	5.4940539E-03	[illegible]	2.6424584E 02	7.2430671E-04	2.3079496E-02	1.6716634E-05	3.2587356E 02
53750.	5.3221716E-03	[illegible]	2.6369328E 02	7.0311693E-04	2.3735514E-02	1.6688842E-05	3.2553267E 02

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE	PRESSURE RATIO	DENSITY RATIO	VISCOSITY RATIO	MOLECULAR WEIGHT	PRESSURE DIFFERENCE
meters	unitless	unitless	unitless	unitless	newtons cm^{-2}
36000.	5.0940446E-03	6.2231737E-03	8.5967164E-01	2.8964400E 01	1.0118340E 01
36250.	4.9218759E-03	5.9973196E-03	8.6147428E-01		1.0120091E 01
36500.	4.7559539E-03	5.7801666E-03	8.6328131E-01		1.0121778E 01
36750.	4.5960367E-03	5.5713656E-03	8.6509210E-01		1.0123405E 01
37000.	4.4418980E-03	5.3705889E-03	8.6690596E-01		1.0124972E 01
37250.	4.2933116E-03	5.1775097E-03	8.6872227E-01		1.0126483E 01
37500.	4.1500691E-03	4.9918287E-03	8.7054015E-01		1.0127940E 01
37750.	4.0119641E-03	4.8132482E-03	8.7235887E-01		1.0129345E 01
38000.	3.8788028E-03	4.6414896E-03	8.7417755E-01		1.0130699E 01
38250.	3.7503962E-03	4.4762817E-03	8.7599536E-01		1.0132005E 01
38500.	3.6265643E-03	4.3173663E-03	8.7781137E-01		1.0133264E 01
38750.	3.5071328E-03	4.1644938E-03	8.7962462E-01		1.0134479E 01
39000.	3.3919357E-03	4.0174268E-03	8.8143409E-01		1.0135650E 01
39250.	3.2808122E-03	3.8759355E-03	8.8323880E-01		1.0136781E 01
39500.	3.1736099E-03	3.7398026E-03	8.8503755E-01		1.0137871E 01
39750.	3.0701783E-03	3.6088134E-03	8.8682938E-01		1.0138923E 01
40000.	2.9703779E-03	3.4827691E-03	8.8861302E-01		1.0139938E 01
40250.	2.8740708E-03	3.3614740E-03	8.9038732E-01		1.0140917E 01
40500.	2.7811256E-03	3.2447418E-03	8.9215099E-01		1.0141862E 01
40750.	2.6914178E-03	3.1323950E-03	8.9390275E-01		1.0142775E 01
41000.	2.6048221E-03	3.0242574E-03	8.9564131E-01		1.0143656E 01
41250.	2.5212255E-03	2.9201680E-03	8.9736534E-01		1.0144506E 01
41500.	2.4405145E-03	2.8199670E-03	8.9907334E-01		1.0145327E 01
41750.	2.3625819E-03	2.7235030E-03	9.0076388E-01		1.0146119E 01
42000.	2.2873230E-03	2.6306283E-03	9.0243558E-01		1.0146885E 01
42250.	2.2146388E-03	2.5412036E-03	9.0408686E-01		1.0147624E 01
42500.	2.1444333E-03	2.4550942E-03	9.0571612E-01		1.0148338E 01
42750.	2.0766138E-03	2.3721695E-03	9.0732185E-01		1.0149028E 01
43000	2.0110933E-03	2.2923075E-03	9.0890229E-01		1.0149694E 01
43250.	1.9477835E-03	2.2153852E-03	9.1045582E-01		1.0150338E 01
43500.	1.8866062E-03	2.1412925E-03	9.1198069E-01		1.0150960E 01
43750.	1.8274791E-03	2.0699151E-03	9.1347519E-01		1.0151561E 01
44000.	1.7703296E-03	2.0011512E-03	9.1493738E-01	MOLECULAR WEIGHT CONSTANT TO 90,000 METERS	1.0152142E 01
44250.	1.7150819E-03	1.9348955E-03	9.1636553E-01		1.0152704E 01
44500.	1.6616677E-03	1.8710526E-03	9.1775768E-01		1.0153248E 01
44750.	1.6100180E-03	1.8095282E-03	9.1911191E-01		1.0153773E 01
45000.	1.5600692E-03	1.7502324E-03	9.2042631E-01		1.0154281E 01
45250.	1.5117585E-03	1.6930789E-03	9.2169876E-01		1.0154772E 01
45500.	1.4650259E-03	1.6379848E-03	9.2292717E-01		1.0155247E 01
45750.	1.4198133E-03	1.5848697E-03	9.2410953E-01		1.0155707E 01
46000.	1.3760647E-03	1.5336569E-03	9.2524362E-01		1.0156152E 01
46250.	1.3337285E-03	1.4842745E-03	9.2632723E-01		1.0156583E 01
46500.	1.2927508E-03	1.4366493E-03	9.2735821E-01		1.0157000E 01
46750.	1.2530856E-03	1.3907175E-03	9.2833408E-01		1.0157403E 01
47000.	1.2146813E-03	1.3464090E-03	9.2925265E-01		1.0157793E 01
47250.	1.1774943E-03	1.3036640E-03	9.3011150E-01		1.0158172E 01
47500.	1.1414802E-03	1.2624218E-03	9.3090819E-01		1.0158538E 01
47750.	1.1065970E-03	1.2226250E-03	9.3164015E-01		1.0158893E 01
48000.	1.0728034E-03	1.1842175E-03	9.3230493E-01		1.0159236E 01
48250.	1.0400507E-03	1.1471467E-03	9.3289990E-01		1.0159569E 01
48500.	1.0083507E-03	1.1113608E-03	9.3342245E-01		1.0159892E 01
48750.	9.7757896E-04	1.0768128E-03	9.3386976E-01		1.0160205E 01
49000.	9.4752835E-04	1.0432772E-03	9.3417658E-01		1.0160511E 01
49250.	9.1881199E-04	1.0127390E-03	9.3339058E-01		1.0160803E 01
49500.	8.9092617E-04	9.8311651E-04	9.3255587E-01		1.0161086E 01
49750.	8.6584722E-04	9.5437936E-04	9.3167348E-01		1.0161362E 01
50000.	8.3755143E-04	9.2649775E-04	9.3074435E-01		1.0161629E 01
50250.	8.1201663E-04	8.9944376E-04	9.2976943E-01		1.0161889E 01
50500.	7.8722080E-04	8.7319003E-04	9.2874972E-01		1.0162141E 01
50750.	7.6314294E-04	8.4771069E-04	9.2768611E-01		1.0162386E 01
51000	7.3976235E-04	8.2298036E-04	9.2657958E-01		1.0162624E 01
51250.	7.1705927E-04	7.[illegible]397496E-04	9.2543113E-01		1.0162854E 01
51500.	6.9501426E-04	7.7567118E-04	9.2424155E-01		1.0163079E 01
51750.	6.7[illegible]60863E-04	7.5304667E-04	9.2301184E-01		1.0163296E 01
52000.	6.5282434E-04	7.3107990E-04	9.2174293E-01		1.0163508E 01
52250.	6.3264366E-04	7.0975011E-04	9.2043562E-01		1.0163713E 01
52500.	6.1304954E-04	6.8903723E-04	9.1909096E-01		1.0163912E 01
52750.	5.9402534E-04	6.6892195E-04	9.1770983E-01		1.0164106E 01
53000.	5.7555500E-04	6.4938582E-04	9.1629300E-01		1.0164293E 01
53250.	5.5762286E-04	6.3041086E-04	9.1484141E-01		1.0164476E 01
53500.	5.4021380E-04	6.1197981E-04	9.1335599E-01		1.0164653E 01
53750.	5.2331313E-04	5.9407618E-04	9.1183751E-01	2.8964400E 01	1.0164825E 01

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE	PRESSURE	KINETIC TEMPERATURE	VIRTUAL TEMPERATURE	DENSITY	KINEMATIC VISCOSITY	COEFFICIENT OF VISCOSITY	SPEED OF SOUND
meters	newtons cm^{-2}	degrees K	degrees K	kg m^{-3}	m^2 sec^{-1}	newton-sec m^{-2}	m sec^{-1}
54000.	5.1553130E-03	2.6312956E 02	2.6312956E 02	6.8253221E-04	2.4409778E-02	1.6660460E-05	3.2518452E 02
54250.	4.9933376E-03	2.6255506E 02	2.6255506E 02	6.6253418E-04	2.5102866E-02	1.6631507E-05	3.2482934E 02
54500.	4.8361087E-03	2.6197010E 02	2.6197010E 02	6.4310530E-04	2.5815361E-02	1.6601996E-05	3.2446728E 02
54750.	4.6834927E-03	2.6137502E 02	2.6137502E 02	6.2422839E-04	2.6547884E-02	1.6571943E-05	3.2409855E 02
55000.	4.5353597E-03	2.6077015E 02	2.6077015E 02	6.0588697E-04	2.7301070E-02	1.6541363E-05	3.2372332E 02
55250.	4.3915860E-03	2.6015581E 02	2.6015581E 02	5.8806537E-04	2.8075569E-02	1.6510270E-05	3.2334178E 02
55500.	4.2520468E-03	2.5953237E 02	2.5953237E 02	5.7074782E-04	2.8872090E-02	1.6478682E-05	3.2295411E 02
55750.	4.1166255E-03	2.5890011E 02	2.5890011E 02	5.5391979E-04	2.9691323E-02	1.6446611E-05	3.2256049E 02
56000.	3.9852059E-03	2.5825934E 02	2.5825934E 02	5.3756684E-04	3.0534011E-02	1.6414072E-05	3.2216108E 02
56250.	3.8576765E-03	2.5761043E 02	2.5761043E 02	5.2167510E-04	3.1400924E-02	1.6381081E-05	3.2175609E 02
56500.	3.7339278E-03	2.5695369E 02	2.5695369E 02	5.0623109E-04	3.2292865E-02	1.6347652E-05	3.2134569E 02
56750.	3.6138545E-03	2.5628940E 02	2.5628940E 02	4.9122195E-04	3.3210649E-02	1.6313800E-05	3.2093004E 02
57000.	3.4973535E-03	2.5561786E 02	2.5561786E 02	4.7663518E-04	3.4155129E-02	1.6279536E-05	3.2050931E 02
57250.	3.3843247E-03	2.5493941E 02	2.5493941E 02	4.6245854E-04	3.5127209E-02	1.6244878E-05	3.2008368E 02
57500.	3.2746712E-03	2.5425435E 02	2.5425435E 02	4.4868036E-04	3.6127810E-02	1.6209839E-05	3.1965334E 02
57750.	3.1682985E-03	2.5356290E 02	2.5356290E 02	4.3528944E-04	3.7157872E-02	1.6174430E-05	3.1921839E 02
58000.	3.0651143E-03	2.5286545E 02	2.5286545E 02	4.2227457E-04	3.8218422E-02	1.6138668E-05	3.1877907E 02
58250.	2.9650293E-03	2.5216226E 02	2.5216226E 02	4.0962520E-04	3.9310484E-02	1.6102565E-05	3.1833552E 02
58500.	2.8679566E-03	2.5145360E 02	2.5145360E 02	3.9733101E-04	4.0435140E-02	1.6066135E-05	3.1788789E 02
58750.	2.7738122E-03	2.5073975E 02	2.5073975E 02	3.8538216E-04	4.1593494E-02	1.6029391E-05	3.1743634E 02
59000.	2.6825136E-03	2.5002101E 02	2.5002101E 02	3.7376892E-04	4.2786719E-02	1.5992346E-05	3.1698105E 02
59250.	2.5939802E-03	2.4929760E 02	2.4929760E 02	3.6248189E-04	4.4016023E-02	1.5955011E-05	3.1652214E 02
59500.	2.5081352E-03	2.4856981E 02	2.4856981E 02	3.5151213E-04	4.5282651E-02	1.5917401E-05	3.1605979E 02
59750.	2.4249023E-03	2.4783793E 02	2.4783793E 02	3.4085073E-04	4.6587926E-02	1.5879529E-05	3.1559415E 02
60000.	2.3442082E-03	2.4710222E 02	2.4710222E 02	3.3048920E-04	4.7933204E-02	1.5841407E-05	3.1512538E 02
60250.	2.2659808E-03	2.4636295E 02	2.4636295E 02	3.2041923E-04	4.9319911E-02	1.5803048E-05	3.1465363E 02
60500.	2.1901511E-03	2.4562030E 02	2.4562030E 02	3.1063299E-04	5.0749477E-02	1.5764462E-05	3.1417902E 02
60750.	2.1166509E-03	2.4487455E 02	2.4487455E 02	3.0112260E-04	5.2223448E-02	1.5725661E-05	3.1370170E 02
61000.	2.0454141E-03	2.4412598E 02	2.4412598E 02	2.9188045E-04	5.3743437E-02	1.5686659E-05	3.1322185E 02
61250.	1.9763771E-03	2.4337476E 02	2.4337476E 02	2.8289940E-04	5.5311054E-02	1.5647464E-05	3.1273755E 02
61500.	1.9094769E-03	2.4262118E 02	2.4262118E 02	2.7417222E-04	5.6928059E-02	1.5608093E-05	3.1225500E 02
61750.	1.8446531E-03	2.4186543E 02	2.4186543E 02	2.6569211E-04	5.8596209E-02	1.5568551E-05	3.1176829E 02
62000.	1.7818466E-03	2.4110778E 02	2.4110778E 02	2.5745233E-04	6.0317397E-02	1.5528854E-05	3.1127960E 02
62250.	1.7209993E-03	2.4034843E 02	2.4034843E 02	2.4944634E-04	6.2093563E-02	1.5489012E-05	3.1078904E 02
62500.	1.6620553E-03	2.3958754E 02	2.3958754E 02	2.4166791E-04	6.3926700E-02	1.5449032E-05	3.1029671E 02
62750.	1.6049612E-03	2.3882540E 02	2.3882540E 02	2.3411097E-04	6.5818912E-02	1.5408929E-05	3.0980278E 02
63000.	1.5496626E-03	2.3806212E 02	2.3806212E 02	2.2676949E-04	6.7772384E-02	1.5368709E-05	3.0930732E 02
63250.	1.4961084E-03	2.3729799E 02	2.3729799E 02	2.1963763E-04	6.9789435E-02	1.5328386E-05	3.0881052E 02
63500.	1.4442482E-03	2.3653317E 02	2.3653317E 02	2.1270982E-04	7.1872414E-02	1.5287968E-05	3.0831246E 02
63750.	1.3940340E-03	2.3576784E 02	2.3576784E 02	2.0598070E-04	7.4023755E-02	1.5247465E-05	3.0781327E 02
64000.	1.3454170E-03	2.3500217E 02	2.3500217E 02	1.9944483E-04	7.6246075E-02	1.5206885E-05	3.0731304E 02
64250.	1.2983516E-03	2.3423638E 02	2.3423638E 02	1.9309709E-04	7.8542044E-02	1.5166240E-05	3.0681192E 02
64500.	1.2527926E-03	2.3347064E 02	2.3347064E 02	1.8693243E-04	8.0914468E-02	1.5125538E-05	3.0631001E 02
64750.	1.2086961E-03	2.3270509E 02	2.3270509E 02	1.8094601E-04	8.3366234E-02	1.5084787E-05	3.0580740E 02
65000.	1.1660196E-03	2.3193981E 02	2.3193981E 02	1.7513312E-04	8.5900316E-02	1.5043991E-05	3.0530415E 02
65250.	1.1247208E-03	2.3117513E 02	2.3117513E 02	1.6948893E-04	8.8520038E-02	1.5003167E-05	3.0480046E 02
65500.	1.0847607E-03	2.3041111E 02	2.3041111E 02	1.6400922E-04	9.1228521E-02	1.4962319E-05	3.0429636E 02
65750.	1.0460989E-03	2.2964788E 02	2.2964788E 02	1.5868945E-04	9.4029269E-02	1.4921453E-05	3.0379196E 02
66000.	1.0086976E-03	2.2888563E 02	2.2888563E 02	1.5352539E-04	9.6925850E-02	1.4880579E-05	3.0328736E 02
66250.	9.7251890E-04	2.2812446E 02	2.2812446E 02	1.4851282E-04	9.9922040E-02	1.4839704E-05	3.0278264E 02
66500.	9.3752730E-04	2.2736447E 02	2.2736447E 02	1.4364783E-04	1.0302162E-01	1.4798833E-05	3.0227787E 02
66750.	9.0368733E-04	2.2660580E 02	2.2660580E 02	1.3892644E-04	1.0622867E-01	1.4757972E-05	3.0177313E 02
67000.	8.7096431E-04	2.2584865E 02	2.2584865E 02	1.3434472E-04	1.0954754E-01	1.4717133E-05	3.0126856E 02
67250.	8.3932542E-04	2.2509302E 02	2.2509302E 02	1.2989908E-04	1.1298245E-01	1.4676317E-05	3.0076415E 02
67500.	8.0873778E-04	2.2433905E 02	2.2433905E 02	1.2558582E-04	1.16[illegible]3808E-01	1.4635530E-05	3.0026000E 02
67750.	7.7916990E-04	2.2358690E 02	2.2358690E 02	1.2140136E-[illegible]	1.[illegible]21926E-01	1.4594782E-05	2.9975623E 02
68000.	7.5059128E-04	2.2283655E 02	2.2283655E 02	1.1734236E-04	1.2403084E-01	1.4554073E-05	2.9925283E 02
68250.	7.2297136E-04	2.2208819E 02	2.2208819E 02	1.1340531E-04	1.2797823E-01	1.4513411E-05	2.9874991E 02
68500.	6.9628181E-04	2.2134183E 02	2.2134183E 02	1.0958706E-04	1.3206667E-01	1.4472799E-05	2.9824749E 02
68750.	6.7049399E-04	2.2059755E 02	2.2059755E 02	1.0588440E-04	1.3630186E-01	1.4432241E-05	2.97[illegible]4563E 02
69000.	6.4558010E-04	2.1985545E 02	2.1985545E 02	1.0229411E-04	1.4068984E-01	1.4391743E-05	2.9724[illegible] 02
69250.	6.2151386E-04	2.1911562E 02	2.1911562E 02	9.8813258E-05	1.4523667E-01	1.4351309E-05	2.96743[illegible]E 02
69500.	5.9826908E-04	2.1837805E 02	2.1837805E 02	9.5438879E-05	1.4994875E-01	1.4310941E-05	2.9624399E 02
69750.	5.7582031E-04	2.1764278E 02	2.1764278E 02	9.2168063E-05	1.5483280E-01	1.4270640E-05	2.9574485E 02
70000.	5.5414297E-04	2.1690992E 02	2.1690992E 02	8.8997983E-05	1.5989589E-01	1.4230412E-05	2.9524650E 02
70250.	5.3321321E-04	2.1617939E 02	2.1617939E 02	8.5925955E-05	1.6514514E-01	1.4190254E-05	2.9474890E 02
70500.	5.1300769E-04	2.1545138E 02	2.1545138E 02	8.2949228E-05	1.7058841E-01	1.4150177E-05	2.9425218E 02
70750.	4.9350380E-04	2.1472581E 02	2.1472581E 02	8.0065238E-05	1.7623349E-01	1.4110177E-05	2.9375629E 02
71000.	4.7467952E-04	2.1400271E 02	2.1400271E 02	7.7271433E-05	1.8208870E-01	1.4070255E-05	2.9326126E 02
71250.	4.5651352E-04	2.1328214E 02	2.1328214E 02	[illegible].4565325E-05	1.8816272E-01	1.4030415E-05	2.9276712E 02
71500.	4.3898500E-04	2.1256401E 02	2.1256401E 02	7.1944517E-05	1.9446448E-01	1.39[illegible]653E-05	2.9227382E 02
71750.	4.2207370E-04	2.1184835E 02	2.1184835E 02	6.9406629E-05	2.0100344E-01	1.3950971E-05	2.9178139E 02

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE	PRESSURE RATIO	DENSITY RATIO	VISCOSITY RATIO	MOLECULAR WEIGHT	PRESSURE DIFFERENCE
meters	unitless	unitless	unitless	unitless	newtons cm^{-2}
54000.	5.0690643E-04	5.7668378E-04	9.1028678E-01	2.8964400E 01	1.0164992E 01
54250.	4.9097988E-04	5.5978708E-04	9.0870485E-01		1.0165154E 01
54500.	4.7552003E-04	5.4337127E-04	9.0709243E-01		1.0165311E 01
54750.	4.6051375E- 4	5.2742183E-04	9.0545042E-01		1.0165464E 01
55000.	4.4594829E-04	5.1192483E-04	9.0377960E-01		1.0165612E 01
55250.	4.3181145E-04	4.9686704E-04	9.0208077E-01		1.0165755E 01
55500.	4.1809098E-04	4.8223513E-04	9.0035490E-01		1.0165895E 01
55750.	4.0477541E-04	4.6801682E-04	8.9860260E-01		1.0166030E 01
56000.	3.9185332E-04	4.5419992E-04	8.9682474E-01		1.0166162E 01
56250.	3.7931373E-04	4.4077271E-04	8.9502219E-01		1.0166289E 01
56500.	3.6714590E-04	4.2772378E-04	8.9319574E-01		1.0166413E 01
56750.	3.5533945E-04	4.1504229E-04	8.9134611E-01		1.0166533E 01
57000.	3.4388426E-04	4.0271766E-04	8.8947403E-01		1.0166650E 01
57250.	3.3277048E-04	3.9073956E-04	8.8758039E-01		1.0166763E 01
57500.	3.2198857E-04	3.7909814E-04	8.8566595E-01		1.0166872E 01
57750.	3.1152927E-04	3.6778390E-04	8.8373126E-01		1.0166979E 01
58000.	3.0138347E-04	3.5678740E-04	8.8177731E-01		1.0167082E 01
58250.	2.9154242E-04	3.4609972E-04	8.7980474E-01		1.0167182E 01
58500.	2.8199755E-04	3.3571214E-04	8.7781430E-01		1.0167279E 01
58750.	2.7274061E-04	3.2[illegible].634E-04	8.7580669E-01		1.0167373E 01
59000.	2.6376350E-04	3.1580411E-04	8.7378265E-01		1.0167464E 01
59250.	2.5505827E-04	3.0626749E-04	8.7174278E-01		1.0167553E 01
59500.	2.4661739E-04	2.9699894E-04	8.6968786E-01		1.0167639E 01
59750.	2.3843336E-04	2.8799093E-04	8.6761861E-01		1.0167722E 01
60000.	2.3049894E-04	2.7923629E-04	8.6553571E-01		1.0167803E 01
60250.	2.2280707E-04	2.7072799E-04	8.6343989E-01		1.0167881E 01
60500.	2.1535097E-04	2.6245942E-04	8.6133162E-01		1.0167957E 01
60750.	2.0812393E-04	2.5442392E-04	8.5921162E-01		1.0168030E 01
61000.	2.0111943E-04	2.4661506E-04	8.5708065E-01		1.0168101E 01
61250.	1.9433122E-04	2.3902681E-04	8.5493916E-01		1.0168171E 01
61500.	1.8775312E-04	2.3165306E-04	8.5278798E-01		1.0168238E 01
61750.	1.8137920E-04	2.2448806E-04	8.5062753E-01		1.0168302E 01
62000.	1.7520362E-04	2.1752612E-04	8.4845861E-01	MOLECULAR WEIGHT CONSTANT TO 90,000 METERS	1.0168365E 01
62250.	1.6922068E-04	2.1076172E-04	8.4628174E-01		1.0168426E 01
62500.	1.6342490E-04	2.0418957E-04	8.4409732E-01		1.0168485E 01
62750.	1.5781101E-04	1.9780458E-04	8.4190620E-01		1.0168542E 01
63000.	1.5237367E-04	1.9160163E-04	8.3970866E-01		1.0168597E 01
63250.	1.4710784E-04	1.8557580E-04	8.3750552E-01		1.0168651E 01
63500.	1.4200859E-04	1.7972236E-04	8.3529718E-01		1.0168703E 01
63750.	1.3707117E-04	1.7403681E-04	8.3308420E-01		1.0168753E 01
64000.	1.3229081E-04	1.6851453E-04	8.3086702E-01		1.0168802E 01
64250.	1.2766301E-04	1.6315121E-04	8.2864624E-01		1.0168849E 01
64500.	1.2318333E-04	1.5794259E-04	8.2642241E-01		1.0168894E 01
64750.	1.1884746E-04	1.5288455E-04	8.2419587E-01		1.0168938E 01
65000.	1.1465120E-04	1.4797314E-04	8.2196686E-01		1.0168981E 01
65250.	1.1059041E-04	1.4320426E-04	8.1973635E-01		1.0169022E 01
65500.	1.066[illegible]26E-04	1.3857435E-04	8.1750449E-01		1.0169062E 01
65750.	1.0[illegible]85976E-04	1.3407958E-04	8.1527168E-01		1.0169101E 01
66000.	9.9182203E-05	1.2971638E-04	8.1303844E-01		1.0169138E 01
66250.	9.5624859E-05	1.2548116E-04	8.1080512E-01		1.0169174E 01
66500.	9.2184241E-05	1.2137064E-04	8.0857201E-01		1.0169210E 01
66750.	8.8856859E-05	1.1738146E-04	8.0633949E-01		1.0169243E 01
67000.	8.5639302E-05	1.1351028E-04	8.0410815E-01		1.0169276E 01
67250.	8.2528344E-05	1.0975408E-04	8.0187805E-01		1.0169308E 01
67500.	7.9520754E-05	1.0610972E-04	7.9964957E-01		1.0169338E 01
67750.	7.6613433E-05	1.0257420E-04	7.9742320E-01		1.0169368E 01
68000.	7.3803384E-05	9.9144681E-05	7.9519892E-01		1.0169396E 01
68250.	7.1087601E-05	9.5818192E-05	7.9297726E-01		1.0169424E 01
68500.	6.8463297E-05	9.2592089E-05	7.9075834E-01		1.0169451E 01
68750.	6.5927658E-05	8.9463636E-05	7.8854234E-01		1.0169477E 01
69000.	6.3477950E-05	8.6430142E-05	7.8632962E-01		1.0169501E 01
69250.	6.1111589E-05	8.3489105E-05	7.8412042E-01		1.0169525E 01
69500.	5.8826000E-05	8.0638031E-05	7.8191479E-01		1.0169549E [illegible]1
69750.	5.6[illegible]8680E-05	7.7874460E-05	7.7971284E-01		1.0169571E 01
70000.	5.4487212E-05	7.5196002E-05	7.7751489E-01		1.0169593E 01
70250.	5.2429252E-05	7.2600390E-05	7.7532077E-01		1.0169614E 01
70500.	5.0442504E-05	7.0085300E-05	7.7313105E-01		1.0169634E 01
70750.	4.8524745E-05	6.7648565E-05	7.7094553E-01		1.0169654E 01
71000.	4.[illegible]673810E-05	6.5288028E-05	7.6876431E-01		1.0169672E 01
71250.	4.4887602E-05	6.3001588E-05	7.6658753E-01		1.0169691E 01
71500.	4.3164076E-05	6.0787221E-05	7.6441507E-01		1.0169708E 01
71750.	4.1501238E-05	5.8642914E-05	7.6224694E-01	2.8964400E 01	1.0169725E 01

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE	PRESSURE	KINETIC TEMPERATURE	VIRTUAL TEMPERATURE	DENSITY	KINEMATIC VISCOSITY	COEFFICIENT OF VISCOSITY	SPEED OF SOUND
meters	newtons cm^{-2}	degrees K	degrees K	kg m^{-3}	m^{2} sec^{-1}	newton-sec m^{-2}	m sec^{-1}
72000.	4.0576003E-04	2.1113518E 02	2.1113518E 02	6.69[illegible]9356E-05	2.0778947E-01	1.3911371E-05	2.9128985E 02
72250.	3.9002491E-04	2.1042441E 02	2.1042441E 02	6.4570475E-05	2.1483266E-01	1.3871847E-05	2.9079913E 02
72500.	3.7484991E-04	2.0971612E 02	2.0971612E 02	6.2267774E-05	2.2214388E-01	1.3832405E-05	2.9030931E 02
72750.	3.6021682E-04	2.0901017E 02	2.0901017E 02	6.0039119E-05	2.2973417E-01	1.3793037E-05	2.8982028E 02
73000.	3.4610846E-04	2.0830656E 02	2.0830656E 02	5.7882463E-05	2.3761504E-01	1.3753744E-05	2.8933204E 02
73250.	3.3250751E-04	2.0760531E 02	2.0760531E 02	5.5795702E-05	2.4579859E-01	1.3714527E-05	2.8884462E 02
73500.	3.1939768E-04	2.0690623E 02	2.0690623E 02	5.3776921E-05	2.5429823E-01	1.3675376E-05	2.8835789E 02
73750.	3.0676280E-04	2.0620942E 02	2.0620942E 02	5.1824119E-05	2.6312645E-01	1.3636297E-05	2.8787192E 02
74000.	2.9458748E-04	2.0551462E 02	2.0551462E 02	4.9935490E-05	2.7229680E-01	1.3597275E-05	2.8738653E 02
74250.	2.8285647E-04	2.0482191E 02	2.0482191E 02	4.8109125E-05	2.8182420E-01	1.3558316E-05	2.8690179E 02
74500.	2.7155515E-04	2.0413113E 02	2.0413113E 02	4.[illegible]343256E-05	2.9172336E-01	1.3519410E-05	2.8641758E 02
74750.	2.6066926E-04	2.0344220E 02	2.0344220E 02	4.4636129E-05	3.0200992E-01	1.3480554E-05	2.8593385E 02
75000.	2.5018505E-04	2.0275499E 02	2.0275499E 02	4.2986051E-05	3.1270005E-01	1.3441740E-05	2.8545051E 02
75250.	2.4008915E-04	2.0206947E 02	2.0206947E 02	4.1391349E-05	3.2381085E-01	1.3402968E-05	2.8496755E 02
75500.	2.3036834E-04	2.0138545E 02	2.0138545E 02	3.9850378E-05	3.3536007E-01	1.3364226E-05	2.8448482E 02
75750.	2.2101015E-04	2.0070282E 02	2.0070282E 02	3.8361580E-05	3.4736598E-01	1.3325508E-05	2.8400225E 02
76000.	2.1200230E-04	2.0002147E 02	2.0002147E 02	3.6923403E-05	3.5984789E-01	1.3286809E-05	2.8351977E 02
76250.	2.0333298E-04	1.9934132E 02	1.9934132E 02	3.5534339E-05	3.7282595E-01	1.3248124E-05	2.8303733E 02
76500.	1.9499040E-04	1.9866205E 02	1.9866205E 02	3.4192910E-05	3.8632084E-01	1.3209434E-05	2.8255468E 02
76750.	1.8696371E-04	1.9798364E 02	1.9798364E 02	3.2897717E-05	4.0035419E-01	1.3170739E-05	2.8207183E 02
77000.	1.7924187E-04	1.9730592E 02	1.9730592E 02	3.1647331E-05	4.1494902E-01	1.3132029E-05	2.8158863E 02
77250.	1.7181453E-04	1.9662865E 02	1.9662865E 02	3.0440435E-05	4.3012822E-01	1.3093290E-05	2.8110492E 02
77500.	1.6467127E-04	1.9595169E 02	1.9595169E 02	2.9275652E-05	4.4591716E-01	1.3054515E-05	2.8062060E 02
77750.	1.5780237E-04	1.9527487E 02	1.9527487E 02	2.8151717E-05	4.6234101E-01	1.3015694E-05	2.8013555E 02
78000.	1.5119831E-04	1.9459798E 02	1.9459798E 02	2.7067389E-05	4.7942609E-01	1.2976813E-05	2.7964961E 02
78250.	1.4484968E-04	1.9392081E 02	1.9392081E 02	2.6021414E-05	4.9720054E-01	1.2937861E-05	2.7916261E 02
78500.	1.3874759E-04	1.9324316E 02	1.9324316E 02	2.5012613E-05	5.1569290E-01	1.2898827E-05	2.7867443E 02
78750.	1.3288332E-04	1.9256477E 02	1.9256477E 02	2.4039828E-05	5.3493286E-01	1.2859694E-05	2.7818485E 02
79000.	1.2724843E-04	1.9188547E 02	1.9188547E 02	2.3101922E-05	5.[illegible]495180E-01	1.2820453E-05	2.7769374E 02
79250.	1.2183471E-04	1.9120492E 02	1.9120492E 02	2.2197789E-05	5.7578186E-01	1.2781084E-05	2.7720087E 02
79500.	1.1663428E-04	1.9052299E 02	1.9052299E 02	2.1324351E-05	5.9745705E-01	1.2741579E-05	2.7670611E 02
79750.	1.1163954E-04	1.8983932E 02	1.8983932E 02	2.0486587E-05	6.2001130E-01	1.2701915E-05	2.7620920E 02
80000.	1.0684305E-04	1.8915372E 02	1.8915372E 02	1.9677466E-05	6.4348133E-01	1.2662082E-05	2.7570998E 02
80250.	1.0223758E-04	1.8846591E 02	1.8846591E 02	1.8897985E-05	6.6790522E-01	1.2622063E-05	2.7520826E 02
80500.	9.7816271E-05	1.8777551E 02	1.8777551E 02	1.8147211E-05	6.9332055E-01	1.2581835E-05	2.7470371E 02
80750.	9.3512375E-05	1.8708234E 02	1.8708234E 02	1.7424191E-05	7.1976859E-01	1.2541385E-05	2.7419621E 02
81000.	8.9499401E-05	1.8638606E 02	1.8638606E 02	1.6728017E-05	7.4729094E-01	1.2500695E-05	2.7368549E 02
81250.	8.5591011E-05	1.8568642E 02	1.8568642E 02	1.6057790E-05	7.7593164E-01	1.2459747E-05	2.7317133E 02
81500.	8.1841182E-05	1.8498297E 02	1.8498297E 02	1.5412671E-05	8.0573418E-01	1.2418516E-05	2.7265341E 02
81750.	7.8244016E-05	1.8427542E 02	1.8427542E 02	1.4791815E-05	8.3674524E-01	1.2376981E-05	2.7213146E 02
82000.	7.4793850E-05	1.8356358E 02	1.8356358E 02	1.4194402E-05	8.6901376E-01	1.2335131E-05	2.7160535E 02
82250	7.1485156E-05	1.8284694E 02	1.8284694E 02	1.3619650E-05	9.0258818E-01	1.2292935E-05	2.7107464E 02
82500.	6.8312650E-05	1.8212515E 02	1.8212515E 02	1.3066791E-05	9.3751932E-01	1.2250370E-05	2.7053908E 02
82750.	6.5271214E-05	1.8139796E 02	1.8139796E 02	1.2535078E-05	9.7386069E-01	1.2207420E-05	2.6999844E 02
83000.	6.2355810E-05	1.8066486E 02	1.8066486E 02	1.2023779E-05	1.0116662E 00	1.2164052E-05	2.6945229E 02
83250.	5.9552895E-05	1.8065000E 02	1.8065000E 02	1.1484251E-05	1.0591176E 00	1.2163172E-05	2.6944122E 02
83500.	5.6875955E-05	1.8065000E 02	1.8065000E 02	1.0968027E-05	1.1089663E 00	1.2163172E-05	2.6944122E 02
83750.	5.4319540E-05	1.8065000E 02	1.8065000E 02	1.0475044E-05	1.1611571E 00	1.2163172E-05	2.6944122E 02
84000.	5.1878215E-05	1.8065000E 02	1.8065000E 02	1.0004256E-05	1.2157997E 00	1.2163172E-05	2.6944122E 02
84250.	4.9546789E-05	1.8065000E 02	1.8065000E 02	9.5546614E-06	1.2730092E 00	1.2163172E-05	2.6944122E 02
84500.	4.7320307E-05	1.8065000E 02	1.8065000E 02	9.1253040E-06	1.3329060E 00	1.2163172E-05	2.6944122E 02
84750.	4.5194038E-05	1.8065000E 02	1.8065000E 02	8.7152717E-06	1.3956160E 00	1.2163172E-05	2.6944122E 02
85000.	4.3163465E-05	1.8065000E 02	1.8065000E 02	8.3236[illegible]E-06	1.4612710E 00	1.2163172E-05	2.6944122E 02
85250.	4.1224272E-05	1.8065000E 02	1.8065000E 02	7.9497374E-06	1.5300093E 00	1.2163172E-05	2.6944122E 02
85500.	3.9372342E-05	1.8065000E 02	1.8065000E 02	7.5926090E-06	1.6019753E 00	1.2163172E-05	2.6944122E 02
85750.	3.7603741E-05	1.8065000E 02	1.8065000E 02	7.2515500E-06	1.6773203E 00	1.2163172E-05	2.6944122E 02
86000.	3.5914714E-05	1.8065000E 02	1.8065000E 02	6.9758360E-06	1.7562028E 00	1.2163172E-05	2.6944122E 02
86250.	3.4301675E-05	1.8065000E 02	1.8065000E 02	6.6147756E-06	1.8387883E 00	1.2163172E-05	2.6944122E 02
86500.	3.2761198E-05	1.8065000E 02	1.8065000E 02	6.3177083E-06	1.9252[illegible]07E 00	1.2163172E-05	2.6944122E 02
86750.	3.1290016E-05	1.8065000E 02	1.8065000E 02	6.0340037E-06	2.0157714E 00	1.2163172E-05	2.6944122E 02
87000.	2.9885006E-05	1.8065000E 02	1.8065000E 02	5.7630599E-06	2.1105407E 00	1.2163172E-05	2.6944122E 02
87250.	2.8543187E-05	1.8065000E 02	1.8065000E 02	5.5043019E-06	2.2097574E 00	1.2163172E-05	2.6944122E 02
87500.	2.7261712E-05	1.8065000E 02	1.8065000E 02	5.2571808E-06	2.3136302E 00	1.2163172E-05	2.6944122E 02
87750.	2.6037863E-05	1.8065000E 02	1.8065000E 02	5.0211724E-06	2.4223769E 00	1.2163172E-05	2.6944122E 02
88000.	2.4869045E-05	1.8065000E 02	1.8065000E 02	4.7957760E-06	2.5362261E 00	1.2163172E-05	2.6944122E 02
88250.	2.3752779E-05	1.8065000E 02	1.8065000E 02	4.5805140E-06	2.6554165E 00	1.2163172E-05	2.6944122E 02
88500.	2.2[illegible]86698E-05	1.8065000E 02	1.8065000E 02	4.3749296E-06	2.7801984E 00	1.2163172E-05	2.6944122E 02
88750.	2.1568542E-05	1.8065000E 02	1.8065000E 02	4.1785873E-06	2.9108335E 00	1.2163172E-05	2.6944122E 02
89000.	2.0696155E-05	1.8065000E 02	1.8065000E 02	3.9910710E-06	3.0475960E 00	1.2163172E-05	2.6944122E 02
89250.	1.9767475E-05	1.8065000E 02	1.8065000E 02	3.8119832E-06	3.1907728E 00	1.2163172E-05	2.6944122E 02
89500.	1.8880533E-05	1.8065000E 02	1.8065000E 02	3.6409443E-06	3.3406642E 00	1.2163172E-05	2.6944122E 02
89750.	1.8033452E-05	1.8065000E 02	1.8065000E 02	3.4775922E-06	3.4975844E 00	1.2163172E-05	2.6944122E 02

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 **(Continued)**

GEOMETRIC ALTITUDE	PRESSURE RATIO	DENSITY RATIO	VISCOSITY RATIO	MOLECULAR WEIGHT	PRESSURE DIFFERENCE
meters	unitless	unitless	unitless	unitless	newtons cm-2
72000.	3.9897164E-05	5.6566718E-05	7.6008329E-01	2.8964400E 01	1.0169741E 01
72250.	3.8349976E-05	5.4556759E-05	7.5792378E-01		1.0169757E 01
72500.	3.6857865E-05	5.2611166E-05	7.5576[illegible]79E-01		1.0169772E 01
72750.	3.5419037E-05	5.0728135E-05	7.5361782E-01		1.0169787E 01
73000.	3.4031804E-05	4.8905938E-05	7.5147093E-01		1.0169801E 01
73250.	3.2694463E-05	4.7142795E-05	7.4932821E-01		1.0169815E 01
73500.	3.1405413E-05	4.5437091E-05	7.4718909E-01		1.0169828E 01
73750.	3.0163064E-05	4.3787133E-05	7.4505390E-01		1.0169840E 01
74000.	2.8965901E-05	4.2191396E-05	7.4292182E-01		1.0169852E 01
74250.	2.7812427E-05	4.0648267E-05	7.4079321E-01		1.0169864E 01
74500.	2.6701201E-05	3.9156253E-05	7.3866751E-01		1.0169875E 01
74750.	2.5630825E-05	3.7713871E-05	7.3654450E-01		1.0169886E 01
75000.	2.4599944E-05	3.6319690E-05	7.3442382E-01		1.0169897E 01
75250.	2.3607244E-05	3.4972298E-05	7.3230540E-01		1.0169907E 01
75500.	2.2651426E-05	3.3670304E-05	7.3018862E-01		1.0169917E 01
75750.	2.1731263E-05	3.2412392E-05	7.2807317E-01		1.0169926E 01
76000.	2.0845549E-05	3.1197249E-05	7.2595872E-01		1.0169935E 01
76250.	1.9993120E-05	3.0023604E-05	7.2384508E-01		1.0169944E 01
76500.	1.9172819E-05	2.8890207E-05	7.2173114E-01		1.0169952E 01
76750.	1.8383580E-05	2.7795874E-05	7.1961697E-01		1.0169960E 01
77000.	1.7624314E-05	2.6739401E-05	7.1750195E-01		1.0169968E 01
77250.	1.6894006E-05	2.5719673E-05	7.1538536E-01		1.0169975E 01
77500.	1.6191631E-05	2.4735526E-05	7.1326679E-01		1.0169982E 01
77750.	1.5516232E-05	2.3785894E-05	7.1114566E-01		1.0169989E 01
78000.	1.4866875E-05	2.2869726E-05	7.0902130E-01		1.0169996E 01
78250.	1.4242634E-05	2.1985962E-05	7.0689307E-01		1.0170002E 01
78500.	1.3642633E-05	2.1133608E-05	7.0476035E-01		1.0170008E 01
78750.	1.3066017E-05	2.0311685E-05	7.0262225E-01		1.0170014E 01
79000.	1.2511956E-05	1.9519231E-05	7.0047820E-01		1.0170020E 01
79250.	1.1979641E-05	1.8755312E-05	6.9832718E-01		1.0170025E 01
79500.	1.1468298E-05	1.8019019E-05	6.9616009E-01		1.0170030E 01
79750.	1.0977180E-05	1.7309487E-05	6.9400159E-01		1.0170035E 01
80000.	1.0505556E-05	1.6625846E-05	6.9182519E-01	MOLECULAR WEIGHT CONSTANT TO 90,000 METERS	1.0170040E 01
80250.	1.0052714E-05	1.5967249E-05	6.8963866E-01		1.0170045E 01
80500.	9.6179799E-06	1.5332906E-05	6.8744068E-01		1.0170049E 01
80750.	9.2006903E-06	1.4722013E-05	6.8[illegible]23062E-01		1.0170054E 01
81000.	8.8002070E-06	1.4133803E-05	6.8300741E-01		1.0170058E 01
81250.	8.4159068E-06	1.3567517E-05	6.8077012E-01		1.0170061E 01
81500.	8.0471972E-06	1.3022443E-05	6.7851731E-01		1.0170065E 01
81750.	7.6934987E-06	1.2497872E-05	6.76[illegible]4797E-01		1.0170069E 01
82000.	7.3542544E-06	1.1993107E-05	6.7396140E-01		1.0170072E 01
82250.	7.0289205E-06	1.1507488E-05	6.7165588E-01		1.0170076E 01
82500.	6.7169775E-06	1.1040368E-05	6.6933023E-01		1.0170079E 01
82750.	6.4179222E-06	1.0591113E-05	6.6698355E-01		1.0170082E 01
83000.	6.1312594E-06	1.0159108E-05	6.6461403E-01		1.0170085E 01
83250.	5.8556570E-06	9.7032506E-06	6.6456598E-01		1.0170088E 01
83500.	5.5924417E-06	9.2670836E-06	6.6456598E-01		1.0170090E 01
83750.	5.3410771E-06	8.8505540E-06	6.6456598E-01		1.0170093E 01
84000.	5.1010289E-06	8.4527768E-06	6.6456598E-01		1.0170095E 01
84250.	4.8717868E-06	8.0729058E-06	6.6456598E-01		1.0170098E 01
84500.	4.6528635E-06	7.7101340E-06	6.6456598E-01		1.0170100E 01
84750.	4.4437939E-06	7.3636903E-06	6.6456598E-01		1.0170102E 01
85000.	4.2441337E-06	7.0328389E-06	6.6456598E-01		1.0170104E 01
85250.	4.0534588E-06	6.7168766E-06	6.6456598E-01		1.0170106E 01
85500.	3.8713640E-06	6.4151324E-06	6.6456598E-01		1.0170108E 01
85750.	3.6974628E-06	6.1269654E-06	6.6456598E-01		1.0170109E 01
86000.	3.5313858E-06	5.8517637E-06	6.6456598E-01		1.0170111E 01
86250.	3.3727806E-06	5.5889432E-06	6.6456598E-01		1.0170113E 01
86500.	3.2213101E-06	5.3379458E-06	6.6456598E-01		1.0170114E 01
86750.	3.0766532E-06	5.0982386E-06	6.6456598E-01		1.0170116E 01
87000.	2.9385028E-06	4.8693133E-06	6.6456598E-01		1.0170117E 01
87250.	2.8065657E-06	4.6506840E-06	6.6456598E-01		1.0170119E 01
87500.	2.6805622E-06	4.4418869E-06	6.6456598E-01		1.0170120E 01
87750.	2.5602248E-06	4.2424792E-06	6.6456598E-01		1.0170121E 01
88000.	2.4452984E-06	4.0520377E-06	6.6456598E-01		1.0170122E 01
88250.	2.3355393E-06	3.8701589E-06	6.6456598E-01		1.0170123E 01
88500.	2.2307148E-06	3.6964570E-06	6.6456598E-01		1.0170124E 01
88750.	2.1306026E-06	3.5305638E-06	6.6456598E-01		1.0170125E 01
89000.	2.0349907E-06	3.3721279E-06	6.6456598E-01		1.0170126E 01
89250.	1.9436763E-06	3.2208134E-06	6.6456598E-01		1.0170127E 01
89500.	1.8564660E-06	3.0762995E-06	6.6456598E-01		1.0170128E 01
89750.	1.7731751E-06	2.9382804E-06	6.6456598E-01	2.8964400E 01	1.0170129E 01

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE	PRESSURE	KINETIC TEMPERATURE	MOLECULAR TEMPERATURE	DENSITY	COEFFICIENT OF VISCOSITY	SPEED OF SOUND
meters	newtons cm^{-2}	degrees K	degrees K	kg m^{-3}	newton-sec m^{-2}	m sec^{-1}
90000.	1.7224435E-05	1.8065000E 02	1.8065000E 02	3.3215805E-06	1.2163172E-05	2.6944122E 02
91000.	1.4357534E-05	1.8359648E 02	1.8365000E 02	2.7234957E-06	1.23402[illegible]E-05	2.7166927E 02
92000.	1.2003841E-05	1.8654122E 02	1.8665000E 02	2.2404228E-06	1.2516126E-05	2.7387919E 02
93000.	1.0065252E-05	1.8948421E 02	1.8965000E 02	1.8488836E-06	1.2690921E-05	2.7607143E 02
94000.	8.4635721E-06	1.9242545E 02	1.9265000E 02	1.5304616E-06	1.2864614E-05	2.7824640E 02
95000.	7.1362419E-06	1.9536494E 02	1.9565000E 02	1.2706545E-06	1.3037217E-05	2.8040450E 02
96000.	6.0330423E-06	1.9830268E 02	1.9865000E 02	1.0579997E-06	1.3208747E-05	2.8254611E 02
97000.	5.1135173E-06	2.0123868E 02	2.0165000E 02	8.8340379E-07	1.3379216E-05	2.8467161E 02
98000.	4.3449711E-06	2.0417293E 02	2.0465000E 02	7.3962724E-07	1.3548638E-05	2.8678136E 02
99000.	3.7008921E-06	2.0710543E 02	2.0765000E 02	6.2088653E-07	1.3717028E-05	2.8887571E 02
100000.	3.1597170E-06	2.1003618E 02	2.1065000E 02	5.2254595E-07	1.3884397E-05	2.9095497E 02
101000.	2.7057645E-06	2.1478336E 02	2.1565000E 02	4.3709746E-07	1.4161117E-05	2.9438718E 02
102000.	2.3253935E-06	2.1951949E 02	2.2065000E 02	3.6713880E-07	1.4435101E-05	2.9778102E 02
103000.	2.0053844E-06	2.2424457E 02	2.2565000E 02	3.0959935E-07	1.4706408E-05	3.0113603E 02
104000.	1.7351148E-06	2.2895861E 02	2.3065000E 02	2.6206711E-07	1.4975097E-05	3.0445407E 02
105000.	1.5060075E-06	2.3366159E 02	2.3565000E 02	2.2263706E-07	1.5241223E-05	3.0773633E 02
106000.	1.3111039E-06	2.3835353E 02	2.4065000E 02	1.8979684E-07	1.5504842E-05	3.1098395E 02
107000.	1.1447335E-06	2.4303442E 02	2.4565000E 02	1.6233993E-07	1.5766006E-05	3.1419801E 02
108000.	1.0022554E-06	2.4770427E 02	2.5065000E 02	1.3929915E-07	1.6024767E-05	3.1737952E 02
109000.	8.7985634E-07	2.5236306E 02	2.5565000E 02	1.1989573E-07	1.6281177E-05	3.2052946E 02
110000.	7.7438980E-07	2.5701081E 02	2.6065000E 02	1.0349983E-07	1.6535285E-05	3.2364874E 02
111000.	6.8403258E-07	2.6641332E 02	2.7065000E 02	8.8045367E-08	1.7036783E-05	3.2979880E 02
112000.	6.0696757E-07	2.7578200E 02	2.8065000E 02	7.5342182E-08	1.7529632E-05	3.3583625E 02
113000.	5.4086384E-07	2.8511684E 02	2.9065000E 02	6.4826916E-08	1.8014180E-05	3.4176707E 02
114000.	4.8386073E-07	2.9441785E 02	3.0065000E 02	5.6065657E-08	1.8490756E-05	3.4759671E 02
115000.	4.3446125E-07	3.0368503E 02	3.1065000E 02	4.8721141E-08	1.8959675E-05	3.5333018E 02
116000.	3.9145232E-07	3.1291837E 02	3.2065000E 02	4.2529020E-08	1.9421230E-05	3.5897208E 02
117000.	3.5384426E-07	3.2211787E 02	3.3065000E 02	3.7280470E-08	1.9875702E-05	3.6452667E 02
118000.	3.2082435E-07	3.3128354E 02	3.4065000E 02	3.2809278E-08	2.0323355E-05	3.6999789E 02
119000.	2.9172118E-07	3.4041538E 02	3.5065000E 02	2.8982235E-08	2.0764441E-05	3.7538938E 02
120000.	2.6597710E-07	3.4951338E 02	3.6065000E 02	2.5691890E-08	2.1199197E-05	3.8070451E 02
121000.	2.4341101E-07	3.6839206E 02	3.8065000E 02	2.2276765E-08	2.2050607E-05	3.9111815E 02
122000.	2.2377934E-07	3.8721781E 02	4.0065000E 02	1.9457748E-08	2.2879253E-05	4.0126162E 02
123000.	2.0658100E-07	4.0599062E 02	4.2065000E 02	1.7108315E-08	2.3686639E-05	4.1115493E 02
124000.	1.9141913E-07	4.2471051E 02	4.4065000E 02	1.5133149E-08	2.4474125E-05	4.2081570E 02
125000.	1.7797572E-07	4.4337744E 02	4.6065000E 02	1.3459454E-08	2.5242944E-05	4.3025962E 02
126000.	1.6599345E-07	4.6199146E 02	4.8065000E 02	1.2030946E-08	2.5994216E-05	4.3950065E 02
127000.	1.5526215E-07	4.8055254E 02	5.0065000E 02	1.0803615E-08	2.6728963E-05	4.4855134E 02
128000.	1.4560872E-07	4.9906068E 02	5.2065000E 02	9.7426983E-09	2.7448117E-05	4.5742298E 02
129000.	1.3688945E-07	5.1751589E 02	5.4065000E 02	8.8204658E-09	2.8152533E-05	4.6612582E 02
130000.	1.2898417E-07	5.3591816E 02	5.6065000E 02	8.0146089E-09	2.8842997E-05	4.7466910E 02
131000.	1.2179175E-07	5.5426750E 02	5.8065000E 02	7.3070349E-09	2.9520227E-05	4.8306132E 02
132000.	1.1522650E-07	5.7256391E 02	6.0065000E 02	6.6829568E-09	3.0184890E-05	4.9131021E 02
133000.	1.0921551E-07	5.9080738E 02	6.2065000E 02	6.1302094E-09	3.0837601E-05	4.9942288E 02
134000.	1.0369626E-07	6.0899793E 02	6.4065000E 02	5.6387136E-09	3.1478926E-05	5.0740585E 02
135000.	9.8615005E-08	6.2713553E 02	6.6065000E 02	5.2000715E-09	3.2109396E-05	5.1526515E 02
136000.	9.3925204E-08	6.4522020E 02	6.8065000E 02	4.8072428E-09	3.2729499E-05	5.2300637E 02
137000.	8.9586500E-08	6.6325194E 02	7.0065000E 02	4.4542972E-09	3.3339691E-05	5.3063467E 02
138000.	8.5563661E-08	6.8123074E 02	7.2065000E 02	4.1362113E-09	3.3940400E-05	5.3815483E 02
139000.	8.1825829E-08	6.9915662E 02	7.4065000E 02	3.8487096E-09	3.4532020E-05	5.4557136E 02
140000.	7.8345911E-08	7.1702955E 02	7.6065000E 02	3.5881386E-09	3.5114925E-05	5.5288841E 02
141000.	7.5100009E-08	7.3484955E 02	7.8065000E 02	3.3513623E-09	3.568[illegible]61E-05	5.6010988E 02
142000.	7.2066944E-08	7.5261663E 02	8.0065000E 02	3.1356758E-09	3.6255956E-05	5.6723942E 02
143000.	6.9227957E-08	7.7033076E 02	8.2064999E 02	2.9387408E-09	3.6814717E-05	5.7428046E 02
144000.	6.656633[illegible]E-08	7.8799196E 02	8.4065000E 02	2.7585267E-09	3.7366033E-05	5.8123620E 02
145000.	6.4067172E-08	8.0560023E 02	8.6064999E 02	2.5932640E-09	3.7910175E-05	5.8810970E 02
146000.	6.1717079E-08	8.2315556E 02	8.8065000E 02	2.4414047E-09	3.8447399E-05	5.9490377E 02
147000.	5.9504086E-08	8.4065795E 02	9.0065000E 02	2.3015928E-09	3.8977947E-05	6.0162112E 02
148000.	5.7417393E-08	8.5810742E 02	9.2064999E 02	2.1726345E-09	3.950205[illegible]E-05	6.0826430E 02
149000.	5.5447274E-08	8.7550395E 02	9.4065000E 02	2.0534772E-09	4.0[illegible]0922E-05	6.1483570E 02
150000.	5.3584943E-08	8.9284424E 02	9.6064999E 02	1.9431903E-09	4.0531768E-05	6.2133762E 02
151000.	5.1813260E-08	9.0590969E 02	9.7565000E 02	1.8500549E-09	4.0911817E-05	6.2616974E 02
152000.	5.0126367E-08	9.1894822E 02	9.9065000E 02	1.7627216E-09	4.1288666E-05	6.3096486E 02
153000.	4.8519017E-08	9.3195982E 02	1.0056500E 03	1.6807491E-09	4.1662388E-05	6.3572381E 02
154000.	4.6986357E-08	9.4494449E 02	1.0206500E 03	1.6037353E-09	4.2033057E-05	6.4044740E 02
155000.	4.5523880E-08	9.5790220E 02	1.0356500E 03	1.5313132E-09	[illegible]400743E-05	6.4513641E 02
156000.	4.4127423E-08	9.7083302E 02	1.0506500E 03	1.4631480E-09	4.2765514E-05	6.4979159E 02
157000.	4.2793123E-08	9.8373690E 02	1.0656500E 03	1.3989338E-09	4.3127434E-05	6.5441364E 02
158000.	4.1517377E-08	9.9661385E 02	1.0806500E 03	1.3383898E-09	4.3486565E-05	6.5900328E 02
159000.	4.0296878E-08	1.0094639E 03	1.0956500E 03	1.2812601E-09	4.3842970E-05	6.6356118E 02

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE	PRESSURE RATIO	DENSITY RATIO	VISCOSITY RATIO	MOLECULAR WEIGHT	PRESSURE DIFFERENCE
meters	unitless	unitless	unitless	unitless	newtons cm^{-2}
90000.	1.6936269E-06	2.8064633E-06	6.6456598E-01	2.8964400E 01	1.0170130E 01
91000.	1.4117332E-06	2.3011306E-06	6.7423916E-01	2.8955960E 01	1.0170133E 01
92000.	1.1803016E-06	1.8929737E-06	6.8385054E-01	2.8947520E 01	1.0170135E 01
93000.	9.8968602E-07	1.5621551E-06	6.9340090E-01	2.8939080E 01	1.0170137E 01
94000.	8.3219761E-07	1.2931146E-06	7.0289101E-01	2.8930640E 01	1.0170139E 01
95000.	7.0160521E-07	1.0735989E-06	7.1232166E-01	2.8922200E 01	1.0170140E 01
96000.	5.9321091E-07	8.9392306E-07	7.2169362E-01	2.8913760E 01	1.0170141E 01
97000.	5.0279675E-07	7.4640381E-07	7.3100764E-01	2.8905320E 01	1.0170142E 01
98000.	4.2722794E-07	6.2492440E-07	7.4026446E-01	2.8896880E 01	1.0170143E 01
99000.	3.6389757E-07	5.2459823E-07	7.4946484E-01	2.8888440E 01	1.0170143E 01
100000.	3.1068547E-07	4.4150850E-07	7.5860950E-01	2.8880000E 01	1.0170144E 01
101000.	2.6604969E-07	3.6931154E-07	7.7372877E-01	2.8848000E 01	1.0170144E 01
102000.	2.2864895E-07	3.1020220E-07	7.8869860E-01	2.8816000E 01	1.0170145E 01
103000.	1.9718342E-07	2.6158608E-07	8.0352218E-01	2.8784000E 01	1.0170145E 01
104000.	1.7060862E-07	2.2142523E-07	8.1820267E-01	2.8752000E 01	1.0170145E 01
105000.	1.4808119E-07	1.8811007E-07	8.3274316E-01	2.8720000E 01	1.0170145E 01
106000.	1.2891690E-07	1.6036277E-07	8.4714662E-01	2.8688000E 01	1.0170146E 01
107000.	1.1255820E-07	1.3716394E-07	8.6141597E-01	2.8656000E 01	1.0170146E 01
108000.	9.8548763E-08	1.1769636E-07	8.7555408E-01	2.8624000E 01	1.0170146E [illegible]
109000.	8.6513629E-08	1.0130207E-07	8.8956368E-01	2.8592000E 01	1.0170146E 01
110000.	7.6143421E-08	8.7448876E-08	9.0344751E-01	2.8560000E 01	1.0170146E 01
111000.	6.7258868E-08	7.4391119E-08	9.3084816E-01	2.8511000E 01	1.0170146E 01
112000.	5.9681296E-08	6.3657969E-08	9.5777620E-01	2.8462000E 01	1.0170146E 01
113000.	5.3181515E-08	5.4773431E-08	9.8425070E-01	2.8413000E 01	1.0170147E 01
114000.	4.7576571E-08	4.7370886E-08	1.0102897E 00	2.8364000E 01	1.0170147E 01
115000.	4.2719269E-08	4.1165371E-08	1.0359102E 00	2.8315000E 01	1.0170147E 01
116000.	3.8490339E-08	3.5933537E-08	1.0611285E 00	2.8266000E 01	1.0170147E 01
117000.	3.4792442E-08	3.1498941E-08	1.0859597E 00	2.8216999E 01	1.0170147E 01
118000.	3.1545694E-08	2.7721151E-08	1.1104184E 00	2.8167999E 01	1.0170147E 01
119000.	2.8684067E-08	2.4487613E-08	1.1345183E 00	2.8119000E 01	1.0170147E 01
120000.	2.6152728E-08	2.1707542E-08	1.1582723E 00	2.8070000E 01	1.0170147E 01
121000.	2.3933873E-08	1.8822041E-08	1.2047912E 00	2.8031670E 01	1.0170147E 01
122000.	2.2003549E-08	1.6440203E-08	1.2500664E 00	2.7993340E 01	1.0170147E 01
123000.	2.0312489E-08	1.4455124E-08	1.2941800E 00	2.7955009E 01	1.0170147E 01
124000.	1.8821667E-08	1.2786271E-08	1.3372063E 00	2.7916680E 01	1.0170147E 01
125000.	1.7499817E-08	1.1372135E-08	1.3792127E 00	2.7878349E 01	1.0170147E 01
126000.	1.6321637E-08	1.0165163E-08	1.4202604E 00	2.7840019E 01	1.0170147E 01
127000.	1.5266469E-08	9.1281695E-09	1.4604051E 00	2.7801690E 01	1.0170147E 01
128000.	1.4317268E-08	8.2317816E-09	1.4996980E 00	2.7763360E 01	1.0170147E 01
129000.	1.3459928E-08	7.4525707E-09	1.5381856E 00	2.7725030E 01	1.0170147E 01
130000.	1.2682626E-08	6.7716876E-09	1.5759108E 00	2.7686700E 01	1.0170147E 01
131000.	1.1975410E-08	6.1738456E-09	1.6129130E 00	2.7648370E 01	1.0170147E 01
132000.	1.1329876E-08	5.6465508E-09	1.6492286E 00	2.7610039E 01	1.0170147E 01
133000.	1.0738833E-08	5.1795245E-09	1.6848911E 00	2.7571710E 01	1.0170147E 01
134000.	1.0196142E-08	4.7642509E-09	1.7199315E 00	2.7533379E 01	1.0170147E 01
135000.	9.[illegible]965170E-09	4.3936343E-09	1.7543789E 00	2.7495050E 01	1.0170147E 01
136000.	9.2353829E-09	4.0617262E-09	1.7882598E 00	2.7456720E 01	1.0170147E 01
137000.	8.8087711E-09	3.7635161E-09	1.8215992E 00	2.7418390E 01	1.0170147E 01
138000.	8.4132175E-09	3.4947596E-09	1.8544204E 00	2.7380059E 01	1.0170147E 01
139000.	8.0456877E-09	3.2518442E-09	1.8867451E 00	2.7341730E 01	1.0170147E 01
140000.	7.7035178E-09	3.0316831E-09	1.9185936E 00	2.7303399E 01	1.0170147E 01
141000.	7.3843582E-09	2.8316265E-09	1.9499848E 00	2.7265069E 01	1.0170147E 01
142000.	7.0861259E-09	2.6493891E-09	1.9809368E 00	2.7226740E 01	1.0170147E 01
143000.	6.8069769E-09	2.4829952E-09	2.0114661E 00	2.7188410E 01	1.0170147E 01
144000.	6.5452677E-09	2.3307289E-09	2.0415886E 00	2.7150080E 01	1.0170147E 01
145000.	6.2995325E-09	2.1910956E-09	2.0713192E 00	2.7111750E 01	1.0170147E 01
146000.	6.0684548E-09	2.0627869E-09	2.1006718E 00	2.7073420E 01	1.0170147E 01
147000.	5.8508570E-09	1.9446573E-09	2.1296597E 00	2.7035089E 01	1.0170147E 01
148000.	5.6456797E-09	1.8356981E-09	2.1582954E 00	2.6996760E 01	1.0170147E 01
149000.	5.4513537E-09	1.7350200E-09	2.1865906E 00	2.6958430E 01	1.0170147E 01
150000.	5.2688466E-09	1.6418366E-09	2.2145567E 00	2.6920000E 01	1.0170147E 01
151000.	5.0946420E-09	1.5631448E-09	2.2353216E 00	2.6894000E 01	1.0170147E 01
152000.	4.9287740E-09	1.4893553E-09	2.2559117E 00	2.6868000E 01	1.0170147E 01
153000.	4.7707291E-09	1.4200952E-09	2.2763309E 00	2.6842000E 01	1.0170147E 01
154000.	4.6200277E-09	1.3550249E-09	2.2965834E 00	2.6816000E 01	1.0170147E 01
155000.	4.4762262E-09	1.2938341E-09	2.3166729E 00	2.6790000E 01	1.0170147E 01
156000.	4.3389168E-09	1.2362401E-09	2.3366031E 00	2.6764000E 01	1.0170147E 01
157000.	4.2077191E-09	1.1819844E-09	2.3563775E 00	2.6738000E 01	1.0170147E 01
158000.	4.0822780E-09	1.1308297E-09	2.3759995E 00	2.6712000E 01	1.0170147E 01
159000.	3.9622708E-09	1.0825598E-09	2.3954726E 00	2.6686000E 01	1.0170147E 01

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE	PRESSURE	KINETIC TEMPERATURE	MOLECULAR TEMPERATURE	DENSITY	COEFFICIENT OF VISCOSITY	SPEED OF SOUND
meters	newtons cm-2	degrees K	degrees K	kg m-3	newton-sec m-2	m sec-1
160000.	3.9128496E-08	1.0222870E 03	1.1106500E 03	1.2273083E-09	4.4196706E-05	6.6808798E 02
161000.	3.8006765E-08	1.0304854E 03	1.1206500E 03	1.1814862E-09	4.4431075E-05	6.7108889E 02
162000.	3.6927060E-08	1.0386659E 03	1.1306500E 03	1.1377695E-09	4.4664298E-05	6.7407643E 02
163000.	3.5887447E-08	1.0468284E 03	1.1406500E 03	1.0960438E-09	4.4896393E-05	6.7705080E 02
164000.	3.4886099E-08	1.0549730E 03	1.1506500E 03	1.0562018E-09	4.5127375E-05	6.8001215E 02
165000.	3.3921305E-08	1.0630997E 03	1.1606500E 03	1.0181436E-09	4.5357258E-05	6.8296066E 02
166000.	3.2991411E-08	1.0712083E 03	1.1706500E 03	9.8177412E-10	4.5586058E-05	6.8589650E 02
167000.	3.2094881E-08	1.0792991E 03	1.1806500E 03	9.4700518E-10	4.5813789E-05	6.8881981E 02
168000.	3.1230234E-08	1.0873719E 03	1.1906500E 03	9.1375313E-10	4.6040465E-05	6.9173079E 02
169000.	3.0396097E-08	1.0954267E 03	1.2006500E 03	8.8194002E-10	4.6266100E-05	6.9462955E 02
170000.	2.9591111E-08	1.1034635E 03	1.2106500E 03	8.5149170E-10	4.6490709E-05	6.9751629E 02
171000.	2.8813069E-08	1.1086877E 03	1.2176500E 03	8.2433703E-10	4.6647331E-05	6.9952990E 02
172000.	2.8059993E-08	1.1138985E 03	1.2246500E 03	7.9820295E-10	4.6803460E-05	7.0153775E 02
173000.	2.7330945E-08	1.1190961E 03	1.2316500E 03	7.7304559E-10	4.6959102E-05	7.0353985E 02
174000.	2.6625029E-08	1.1242804E 03	1.2386500E 03	7.4882312E-10	4.7114260E-05	7.0553628E 02
175000.	2.5941384E-08	1.1294514E 03	1.2456500E 03	7.2549574E-10	4.7268939E-05	7.0752708E 02
176000.	2.5279174E-08	1.1346091E 03	1.2526500E 03	7.0302521E-10	4.7423143E-05	7.0951229E 02
177000.	2.4637622E-08	1.1397535E 03	1.2596500E 03	6.8137571E-10	4.7576877E-05	7.1149195E 02
178000.	2.4015958E-08	1.1448846E 03	1.2666500E 03	6.6051251E-10	4.7730144E-05	7.1346613E 02
179000.	2.3413469E-08	1.1500024E 03	1.2736500E 03	6.4040310E-10	4.7882948E-05	7.1543486E 02
180000.	2.2829452E-08	1.1551070E 03	1.2806500E 03	6.2101602E-10	4.8035293E-05	7.1739818E 02
181000.	2.2263246E-08	1.1601982E 03	1.2876500E 03	6.0232157E-10	4.8187184E-05	7.1935616E 02
182000.	2.1714210E-08	1.1652761E 03	1.2946500E 03	5.8429129E-10	4.8338625E-05	7.2130880E 02
183000.	2.1181733E-08	1.1703408E 03	1.3016500E 03	5.6689814E-10	4.8489619E-05	7.2325619E 02
184000.	2.0665225E-08	1.1753922E 03	1.3086500E 03	5.5011615E-10	4.8640170E-05	7.2519835E 02
185000.	2.0164124E-08	1.1804302E 03	1.3156500E 03	5.3392071E-10	4.8790280E-05	7.2713531E 02
186000.	1.9677896E-08	1.1854550E 03	1.3226500E 03	5.1828839E-10	4.8939956E-05	7.2906713E 02
187000.	1.9206011E-08	1.1904665E 03	1.3296500E 03	5.0319647E-10	4.9089199E-05	7.3099384E 02
188000.	1.8747980E-08	1.1954647E 03	1.3366500E 03	4.8862371E-10	4.9238014E-05	7.3291548E 02
189000.	1.8303317E-08	1.2004496E 03	1.3436500E 03	4.7454937E-10	4.9386404E-05	7.3483211E 02
190000.	1.7871564E-08	1.2054212E 03	1.3506500E 03	4.6095390E-10	4.9534373E-05	7.3674375E 02
191000.	1.7451910E-08	1.2085380E 03	1.3556500E 03	4.4846974E-10	4.9639808E-05	7.3810617E 02
192000.	1.7043719E-08	1.2116448E 03	1.3606500E 03	4.3637082E-10	4.9745032E-05	7.3946609E 02
193000.	1.6646644E-08	1.2147417E 03	1.3656500E 03	4.2464403E-10	4.9850045E-05	7.4082351E 02
194000.	1.6260338E-08	1.2178287E 03	1.3706500E 03	4.1327655E-10	4.9954849E-05	7.4217845E 02
195000.	1.5884471E-08	1.2209057E 03	1.3756500E 03	4.0225603E-10	5.0059444E-05	7.4353091E 02
196000.	1.5518716E-08	1.2239729E 03	1.3806500E 03	3.9157048E-10	5.0163831E-05	7.4488092E 02
197000.	1.5162775E-08	1.2270301E 03	1.3856500E 03	3.8120879E-10	5.0267014E-05	7.4622849E 02
198000.	1.4816337E-08	1.2300773E 03	1.3906500E 03	3.7115965E-10	5.0371991E-05	7.4757363E 02
199000.	1.4479118E-08	1.2331147E 03	1.3956500E 03	3.6141266E-10	5.0475764E-05	7.4891635E 02
200000.	1.4150844E-08	1.2361421E 03	1.4006500E 03	3.5195770E-10	5.0579335E-05	7.5025666E 02
201000.	1.3831139E-08	1.2391596E 03	1.4056500E 03	3.4278486E-10	5.0682705E-05	7.5159460E 02
202000.	1.3520045E-08	1.2421672E 03	1.4106500E 03	3.3388477E-10	5.0785874E-05	7.5293015E 02
203000.	1.3217012E-08	1.2451648E 03	1.4156500E 03	3.2524838E-10	5.0888844E-05	7.5426334E 02
204000.	1.2921892E-08	1.2481526E 03	1.4206500E 03	3.1686683E-10	5.0991617E-05	7.5559417E 02
205000.	1.2634456E-08	1.2511304E 03	1.4256500E 03	3.0873182E-10	5.1094193E-05	7.5692267E 02
206000.	1.2354471E-08	1.2540982E 03	1.4306500E 03	3.0083510E-10	5.1196572E-05	7.5824883E 02
207000.	1.2081722E-08	1.2570561E 03	1.4356500E 03	2.9316897E-10	5.1298757E-05	7.5957268E 02
208000.	1.1815994E-08	1.2600042E 03	1.4406500E 03	2.8572584E-10	5.1400748E-05	7.6089423E 02
209000.	1.1557080E-08	1.2629423E 03	1.4456500E 03	2.7849841E-10	5.1502547E-05	7.6221349E 02
210000.	1.1304783E-08	1.2658705E 03	1.4506500E 03	2.7147970E-10	5.1604154E-05	7.6353047E 02
211000.	1.1058912E-08	1.2687887E 03	1.4556500E 03	2.6466296E-10	5.1705571E-05	7.6484517E 02
212000.	1.0819280E-08	1.2716970E 03	1.4606500E 03	2.5804174E-10	5.1806799E-05	7.6615764E 02
213000.	1.0585704E-08	1.2745954E 03	1.4656500E 03	2.5160961E-10	5.1907837E-05	7.6746764E 02
214000.	1.0358013E-08	1.2774839E 03	1.4706500E 03	2.4536062E-10	5.2008688E-05	7.6877581E 02
215000.	1.0136038E-08	1.2803624E 03	1.4756500E 03	2.3928894E-10	5.2109353E-05	7.7008157E 02
216000.	9.9196129E-09	1.2832310E 03	1.4806500E 03	2.3338883E-10	5.2209833E-05	7.7138512E 02
217000.	9.7085841E-09	1.2860897E 03	1.4856500E 03	2.2765497E-10	5.2310127E-05	7.7268646E 02
218000.	9.5027945E-09	1.2889384E 03	1.4906500E 03	2.2208202E-10	5.2410240E-05	7.7398562E 02
219000.	9.3020988E-09	1.2917773E 03	1.4956500E 03	2.1666498E-10	5.2510169E-05	7.7528260E 02
220000.	9.1063540E-09	1.2946062E 03	1.5006500E 03	2.1139897E-10	5.2609917E-05	7.7657742E 02
221000.	8.9154168E-09	1.2974252E 03	1.5056500E 03	2.0627917E-10	5.2709484E-05	7.7787007E 02
222000.	8.7291573E-09	1.3002342E 03	1.5106500E 03	2.0130113E-10	5.2808871E-05	7.7916059E 02
223000.	8.5474434E-09	1.3030333E 03	1.5156500E 03	1.9646042E-10	5.2908080E-05	7.8044897E 02
224000.	8.3701468E-09	1.3058225E 03	1.5206500E 03	1.9175273E-10	5.3007112E-05	7.8173523E 02
225000.	8.1971492E-09	1.3086018E 03	1.5256500E 03	1.8717437E-10	5.3105966E-05	7.8301936E 02
226000.	8.0283282E-09	1.3113712E 03	1.5306500E 03	1.8272038E-10	5.3204644E-05	7.8430142E 02
227000.	7.8635709E-09	1.3141306E 03	1.5356500E 03	1.7838787E-10	5.3303145E-05	7.8558137E 02
228000.	7.7027657E-09	1.3168801E 03	1.5406500E 03	1.7417285E-10	5.3401477E-05	7.8685923E 02
229000.	7.5456031E-09	1.3196197E 03	1.5456500E 03	1.7007170E-10	5.3499634E-05	7.8813503E 02

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE	PRESSURE RATIO	DENSITY RATIO	VISCOSITY RATIO	MOLECULAR WEIGHT	PRESSURE DIFFERENCE
meters	unitless	unitless	unitless	unitless	newtons cm^{-2}
160000.	3.8473873E-09	1.0369750E-09	2.4147999E 00	2.6660000E 01	1.0170147E 01
161000.	3.7370909E-09	9.9825902E-10	2.4276052E 00	2.6634000E 01	1.0170147E 01
162000.	3.6309267E-09	9.6132199E-10	2.4403480E 00	2.6608000E 01	1.0170147E 01
163000.	3.5287047E-09	9.2606717E-10	2.4530291E 00	2.6582000E 01	1.0170147E 01
164000.	3.4302453E-09	8.9240400E-10	2.4656494E 00	2.6556000E 01	1.0170147E 01
165000.	3.3353799E-09	8.6024789E-10	2.4782096E 00	2.6530000E 01	1.0170147E 01
166000.	3.2439463E-09	8.2951866E-10	2.4907107E 00	2.6504000E 01	1.0170147E 01
167000.	3.1557932E-09	8.0014176E-10	2.5031534E 00	2.6478000E 01	1.0170147E 01
168000.	3.0707750E-09	7.7204651E-10	2.5155384E 00	2.6452000E 01	1.0170147E 01
169000.	2.9887562E-09	7.4516704E-10	2.5278666E 00	2.6426000E 01	1.0170147E 01
170000.	2.9096050E-09	7.19[illegible]070E-10	2.5401386E 00	2.6400000E 01	1.0170147E 01
171000.	2.8331025E-09	6.9649723E-10	2.5486960E 00	2.6372500E 01	1.0170147E 01
172000.	2.7590547E-09	6.7441608E-10	2.5572266E 00	2.6345000E 01	1.0170147E 01
173000.	2.6873697E-09	6.5316017E-10	2.5657305E 00	2.6317500E 01	1.0170147E 01
174000.	2.6179591E-09	6.3269417E-10	2.5742079E 00	2.6290000E 01	1.0170147E 01
175000.	2.5507383E-09	6.1298444E-10	2.5826592E 00	2.6262500E 01	1.0170147E 01
176000.	2.4856252E-09	5.9399869E-10	2.5910846E 00	2.6235000E 01	1.0170147E 01
177000.	2.4225433E-09	5.7570663E-10	2.5994842E 00	2.6207500E 01	1.0170147E 01
178000.	2.3614169E-09	5.5807893E-10	2.6078583E 00	2.6180000E 01	1.0170147E 01
179000.	2.3021760E-09	5.4108813E-10	2.6162072E 00	2.6152500E 01	1.0170147E 01
180000.	2.2447514E-09	5.2470765E-10	2.6245309E 00	2.6125000E 01	1.0170147E 01
181000.	2.1890781E-09	5.0891236E-10	2.6328299E 00	2.6097500E 01	1.0170147E 01
182000.	2.1350930E-09	4.9367825E-10	2.6411043E 00	2.6070000E 01	1.0170147E 01
183000.	2.0827361E-09	4.7898246E-10	2.6493542E 00	2.6042500E 01	1.0170147E 01
184000.	2.0319495E-09	4.6480306E-10	2.6575799E 00	2.6015000E 01	1.0170147E 01
185000.	1.9826777E-09	4.5111924E-10	2.6657816E 00	2.5987500E 01	1.0170147E 01
186000.	1.9348683E-09	4.3791121E-10	2.6739595[illegible]	2.5960000E 01	1.0170147E 01
187000.	1.8884693E-09	4.2515978E-10	2.682113[illegible] 00	2.5932500E 01	1.0170147E 01
188000.	1.8434325E-09	4.1284699E-10	2.690244[illegible]E 00	2.5905000E 01	1.0170147E 01
189000.	1.7997101E-09	4.0095532E-10	2.6983523E 00	2.5877500E 01	1.0170147E 01
190000.	1.7572572E-09	3.8946827E-10	2.7064370E 00	2.5850000E 01	1.0170147E 01
191000.	1.7159939E-09	3.7892017E-10	2.7121977E 00	2.5821249E 01	1.0170147E 01
192000.	1.6758577E-09	3.6869758E-10	2.7179469E 00	2.5792499E 01	1.0170147E 01
193000.	1.6368144E-09	3.5878940E-10	2.7236845E 00	2.5763749E 01	1.0170147E 01
194000.	1.5988302E-09	3.4918481E-10	2.7294108E 00	2.5735000E 01	1.0170147E 01
195000.	1.5618723E-09	3.3987338E-10	2.7351256E 00	2.5706249E 01	1.0170147E 01
196000.	1.5259087E-09	3.3084497E-10	2.7408290E 00	2.5677499E 01	1.0170147E 01
197000.	1.4909101E-09	3.2209018E-10	2.7465213E 00	2.5648749E 01	1.0170147E 01
198000.	1.4568458E-09	3.1359948E-10	2.7522024E 00	2.5620000E 01	1.0170147E 01
199000.	1.4236882E-09	3.0536407E-10	2.7578723E 00	2.5591249E 01	1.0170147E 01
200000.	1.3914099E-09	2.9737541E-10	2.7635311E 00	2.5562499E 01	1.0170147E 01
201000.	1.3599841E-09	2.8962511E-10	2.7691790E 00	2.5533749E 01	1.0170147E 01
202000.	1.3293854E-09	2.8210527E-10	2.7748159E 00	2.5505000E 01	1.0170147E 01
203000.	1.2995890E-09	2.7480822E-10	2.7804420E 00	2.5476249E 01	1.0170147E 01
204000.	1.2705708E-09	2.6772650E-10	2.7860572E 00	2.5447499E 01	1.0170147E 01
205000.	1.2423081E-09	2.6085308E-10	2.7916617E 00	2.5418749E 01	1.0170147E 01
206000.	1.2147780E-09	2.5418100E-10	2.7972554E 00	2.5390000E 01	1.0170147E 01
207000.	1.1879593E-09	2.4770375E-10	2.8028386E 00	2.5361249E 01	1.0170147E 01
208000.	1.1618311E-09	2.4141492E-10	2.8084112E 00	2.533249[illegible] 01	1.0170147E 01
209000.	1.1363729E-09	2.3530833E-10	2.8139732E 00	2.5303749E 01	1.0170147E 01
210000.	1.1115654E-09	2.2937809E-10	2.8195248E 00	2.5275000E 01	1.0170147E 01
211000.	1.0873895E-09	2.2361851E-10	2.8250659E 00	2.5246249E 01	1.0170147E 01
212000.	1.0638273E-09	2.1802412E-10	2.8305967E 00	2.5217499E 01	1.0170147E 01
213000.	1.0408604E-09	2.1258950E-10	2.8361172E 00	2.5188749E 01	1.0170147E 01
214000.	1.0184723E-09	2.0730962E-10	2.8416275E 00	2.5160000E 01	1.0170147E 01
215000.	9.9664617E-10	2.0217955E-10	2.8471276E 00	2.5131250E 01	1.0170147E 01
216000.	9.7536570E-10	1.9719443E-10	2.8526176E 00	2.5102499E 01	1.0170147E 01
217000.	9.5461588E-10	1.9234979E-10	2.8580974E 00	2.5073749E 01	1.0170147E 01
218000.	9.3438121E-10	1.8764111E-10	2.8635673E 00	2.5045000E 01	1.0170147E 01
219000.	9.1464741E-10	1.8306416E-10	2.8690272E 00	2.5016250E 01	1.0170147E 01
220000.	8.9540042E-10	1.7861481E-10	2.8744772E 00	2.4987499E 01	1.0170147E 01
221000.	8.7662612E-10	1.7428899E-10	2.8799173E 00	2.4958749E 01	1.0170147E 01
222000.	8.5831180E-10	1.7008296E-10	2.8853475E 00	2.4930000E 01	1.0170147E 01
223000.	8.4044441E-10	1.6599295E-10	2.8907681E 00	2.4901250E 01	1.0170147E 01
224000.	8.2301136E-10	1.6201534E-10	2.8961789E 00	2.4872499E 01	1.0170147E 01
225000.	8.0600103E-10	1.5814675E-10	2.9015801E 00	2.4843749E 01	1.0170147E 01
226000.	7.8940138E-10	1.5438374E-10	2.9069716E 00	2.4815000E 01	1.0170147E 01
227000.	7.7320129E-10	1.5072313E-10	2.9123536E 00	2.4786250E 01	1.0170147E 01
228000.	7.5738960E-10	1.4716178E-10	2.9177261E 00	2.4757499E 01	1.0170147E 01
229000.	7.4199613E-10	1.43[illegible]E-10	2.9230[illegible]E 00	2.47[illegible]E 01	1.0170147E 01

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE	PRESSURE	KINETIC TEMPERATURE	MOLECULAR TEMPERATURE	DENSITY	COEFFICIENT OF VISCOSITY	SPEED OF SOUND
meters	newtons cm^{-2}	degrees K	degrees K	kg m^{-3}	newton-sec m^{-2}	m sec^{-1}
230000.	7.3925818E-09	1.3223493E 03	1.5506500E 03	1.6608106E-10	5.3597617E-05	7.8940877E 02
231000.	7.2428844E-09	1.3241963E 03	1.5546500E 03	1.6229931E-10	5.3675881E-05	7.9042627E 02
232000.	7.0966346E-09	1.3260353E 03	1.5586500E 03	1.5861403E-10	5.3754035E-05	7.9144247E 02
233000.	6.9537457E-09	1.3278662E 03	1.5626500E 03	1.5502254E-10	5.3832081E-05	7.9245737E 02
234000.	6.8141302E-09	1.3296890E 03	1. 566500E 03	[illegible].5152218E-10	5.3910018E-05	7.9347096E 02
235000.	6.6777033E-09	1.3315039E 03	1. 706500E 03	1.4811037E-10	[illegible].3987848E-05	7.9448327E 02
236000.	6.5443868E-09	1.3333106E 03	1 746500E 03	1.4478470E-10	5.4065570E-05	7.9549429E 02
237000.	6.4140990E-09	1.3351093E 03	1. 500E 03	1.4154273E-10	5.4143183E-05	7.9650403E 02
238000.	6.2867616E-09	1.3369000E 03	1.5826500E 03	1.3838208E-10	5.4220692E-05	7.9751249E 02
239000.	6.1623034E-09	1.3386826E 03	1.5866500E 03	1.3530059E-10	5.4298093E-05	7.9851967E 02
240000.	6.0406505E-09	1.3404572E 03	1.5906500E 03	1.3229604E-10	5.4375389E-05	7.9952559E 02
241000.	5.9217323E-09	1.3422237E 03	1.5946500E 03	1.2936630E-10	5.4452580E-05	8.0053023E 02
242000.	5.8054790E-09	1.3439822E 03	1.5986500E 03	1.2650929E-10	5.4529665E-05	8.0153363E 02
243000.	5.6918242E-09	1.3457326E 03	1.6026500E 03	1.2372303E-10	5.4606646E-05	8.0253576E 02
244000.	5.5807045E-09	1.3474750E 03	1.6066500E 03	1.2100561E-10	5.4683524E-05	8.0353664E 02
245000.	5.4720553E-09	1.3492094E 03	1.6106500E 03	1.1835512E-10	5.4760296E-05	8.0453628E 02
246000.	5.3658156E-09	1.3509356E 03	1.6146500E 03	1.1576975E-10	5.4836967E-05	8.0553468E 02
247000.	5.2619249E-09	1.3526538E 03	1.6186500E 03	1.1324771E-10	5.4913533E-05	8.0653186E 02
248000.	5.1603259E-09	1.3543640E 03	1.6226500E 03	1.1078731E-10	5.4989998E-05	8.0752779E 02
249000.	5.0609626E-09	1.3560662E 03	1.6266500E 03	1.0838689E-10	5.5066360E-05	8.0852250E 02
250000.	4.9637800E-09	1.3577603E 03	1.6306500E 03	1.0604484E-10	5.5142621E-05	8.0951596E 02
251000.	4.8687236E-09	1.3594463E 03	1.6346500E 03	1.0375955E-10	5.5218779E-05	8.1050824E 02
252000.	4.7757415E-09	1.3611243E 03	1.6386500E 03	1.0152953E-10	5.5294838E-05	8.1149930E 02
253000.	4.6847841E-09	1.3627942E 03	1.6426500E 03	9.9353300E-11	5.5370796E-05	8.1248914E 02
254000.	4.5958012E-09	1.3644561E 03	1.6466500E 03	9.7229418E-11	5.5446653E-05	8.1347779E 02
255000.	4.5087449E-09	1.3661100E 03	1.6506500E 03	9.5156492E-11	5.5522412E-05	8.1446522E 02
256000.	4.4235698E-09	1.3677558E 03	1.6546500E 03	9.3133194E-11	5.5598070E-05	8.1545147E 02
257000.	4.3402283E-09	1.3693935E 03	1.6586500E 03	9.1158165E-11	5.5673630E-05	8.1643653E 02
258000.	4.2586772E-09	1.3710232E 03	1.6626500E 03	8.9230154E-11	5.5749090E-05	8.1742039E 02
259000.	4.1788747E-09	1.3726449E 03	1.6666500E 03	8.7347945E-11	5.5824453E-05	8.1840308E 02
260000.	4.1007767E-09	1.3742585E 03	1.6706500E 03	8.5510293E-11	5.5899718E-05	8.1938457E 02
261000.	4.0243446E-09	1.3758640E 03	1.6746500E 03	8.3716075E-11	5.5974885E-05	8.2036492E 02
262000.	3.9495377E-09	1.3774615E 03	1.6786500E 03	8.1964134E-11	5.6049955E-05	8.2134407E 02
263000.	3.8763164E-09	1.3790510E 03	1.6826500E 03	8.0253351E-11	5.6124928[illegible]-05	8.2232206E 02
264000.	3.8046447E-09	1.3806324E 03	1.6866500E 03	7.8582690E-11	5.6199805E-05	8.2329890E 02
265000.	3.7344853E-09	1.3822058E 03	1.6906500E 03	7.6951092E-11	5.6274586E-05	8.24274[illegible]E 02
266000.	3.6658013E-09	1.3837711E 03	1.6946500E 03	7.5357531E-11	5.6349271E-05	8.252[illegible]910E 02
267000.	3.5985599E-09	1.3853283E 03	1.6986500E 03	7.3801059E-11	5.6423861E-05	8.2622247E 02
268000.	3.5327263E-09	1.3868776E 03	1.7026500E 03	7.2280703E-11	5.6498355E-05	8.2719469E 02
269000.	3.4682674E-09	1.3884187E 03	1.7066500E 03	7.0795534E-11	5.6572756E-05	8.2816577E 02
270000.	3.4051519E-09	1.3899518E 03	1.7106500E 03	6.9344663E-11	5.6647062E-05	8.2913573E 02
271000.	3.3433475E-09	1.3914769E 03	1.7146500E 03	6.7927213E-11	5.6721274E-05	8.3010454E 02
272000.	3.2828238E-09	1.3929939E 03	1.7186500E 03	6.6542312E-11	5.6795392E-05	8.3107224E 02
273000.	3.2235518E-09	1.3945029E 03	1.7226500E 03	6.5189155E-11	5.6869417E-05	8.3203880E 02
274000.	3.1655008E-09	1.3960038E 03	1.7266500E 03	6.3866904E-11	5.6943349E-05	8.3300422E 02
275000.	3.1086450E-09	1.3974967E 03	1.7306500E 03	6.2574823E-11	5.7017189E-05	8.3396854E 02
276000.	3.0529552E-09	1.3989815E 03	1.7346500E 03	6.1312119E-11	5.7090937E-05	8.3493176E 02
277000.	2.9984053E-09	1.4004583E 03	1.7386500E 03	6.0078065E-11	5.7164592E-05	8.3589386E 02
278000.	2.9449691E-09	1.4019270E 03	1.7426500E 03	5.8871938E-11	5.7238156E-05	8.3685485E 02
279000.	2.8926212E-09	1.4033877E 03	1.7466500E 03	5.7693040E-11	5.7311629E-05	8.3781472E 02
280000.	2.8413364E-09	1.4048403E 03	1.7506500E 03	5.6540688E-11	5.7385010E-05	8.3877352E 02
281000.	2.7910914E-09	1.4062849E 03	1.7546500E 03	5.5414231E-11	5.7458303E-05	8.3973122E 02
282000.	2.7418610E-09	1.4077214E 03	1.7586500E 03	5.4312999E-11	5.7531503E-05	8.4068781E 02
283000.	2.6936236E-09	1.4091499E 03	1.7626500E 03	5.3236388E-11	5.7604614E-05	8.4164335E 02
284000.	2.6463566E-09	1.4105704E 03	1.7666500E 03	5.2183788E-11	5.7677636E-05	8.4259777E 02
285000.	2.6000374E-09	1.4119828E 03	1.7706500E 03	5.1154591E-11	5.7750568E-05	8.4355112E 02
286000.	2.5546459E-09	1.4133871E 03	1.7746500E 03	5.0148246E-11	5.7823412E-05	8.4450340E 02
287000.	2.5101599E-09	1.4147834E 03	1.7786500E 03	4.9164162E-11	5.7896167E-05	8.4545461E 02
288000.	2.4665603E-09	1.4161716E 03	1.7826500E 03	4.8201817E-11	5.7968833E-05	8.4640476E 02
289000.	2.4238261E-09	1.4175518E 03	1.7866500E 03	4.7260654E-11	5.8041411E-05	8.4735382E 02
290000.	2.3819396E-09	1.4189240E 03	1.7906500E 03	4.6340187E-11	5.8113902E-05	8.4830183E 02
291000.	2.3408808E-09	1.4202881E 03	1.7946500E 03	4.5439891E-11	5.8186305E-05	8.4924878E 02
292000.	2.3006322E-09	1.4216441E 03	1.7986500E 03	4.4559293E-11	5.8258622E-05	8.5019467E 02
293000.	2.2611749E-09	1.4229921E 03	1.8026500E 03	4.3697893E-11	5.8330851E-05	8.5113952E 02
294000.	2.2224918E-09	1.4243321E 03	1.8066500E 03	4.2855237E-11	5.8402995E-05	8.5208331E 02
295000.	2.1845663E-09	1.4256640E 03	1.8106500E 03	4.2030879E-11	5.8475052E-05	8.5302607E 02
296000.	2.1473817E-09	1.4269878E 03	1.8146500E 03	4.1224380E-11	5.8547023E-05	8.5396777E 02
297000.	2.1109216E-09	1.4283036E 03	1.8186500E 03	4.0435306E-11	5.8618908E-05	8.5490845E 02
298000.	2.0751696E-09	1.4296114E 03	.8226500E 03	3.9663230E-11	5.8690707E-05	[illegible].5584810E 02
299000.	2.040[illegible]E-09	1.[illegible]309111E 03	1.82[illegible]E 03	3.8907771E-1[illegible]	5.87[illegible]E-05	[illegible].5678670E 02

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE	PRESSURE RATIO	DENSITY RATIO	VISCOSITY RATIO	MOLECULAR WEIGHT	PRESSURE DIFFERENCE
meters	unitless	unitless	unitless	unitless	newtons cm^{-2}
230000.	7.2689034E-10	1.4032486E-10	2.9284427E 00	2.4700000E 01	1.0170147E 01
231000.	7.1217104E-10	1.3712962E-10	2.9327188E 00	2.4670860E 01	1.0170147E 01
232000.	6.9779074E-10	1.3401585E-10	2.9369890E 00	2.4641719E 01	1.0170147E 01
233000.	6.8374090E-10	1.3098134E-10	2.9412532E 00	2.4612580E 01	1.0170147E 01
234000.	6.7001294E-10	1.2802382E-10	2.9455115E 00	2.4583440E 01	1.0170147E 01
235000.	6.5659848E-10	1.2514112E-10	2.9497639E 00	2.4554300E 01	1.0170147E 01
236000.	6.4348988E-10	1.2233121E-10	2.9540105E 00	2.4525160E 01	1.0170147E 01
237000.	6.3067907E-10	1.1959200E-10	2.9582511E 00	2.4496019E [illegible]	1.0170147E 01
238000.	6.1815837E-10	1.1692152E-10	2.9624860E 00	2.4466880E [illegible]	1.0170147E 01
239000.	6.0592077E-10	1.1431791E-10	2.9667150E 00	2.4437740E 01	1.0170147E 01
240000.	5.9395900E-10	1.1177931E-10	2.9709383E 00	2.4408600E 01	1.0170147E 01
241000.	5.8226613E-10	1.0930392E-10	2.9751558E 00	2.4379460E 01	1.0170147E 01
242000.	5.7083530E-10	1.0688998E-10	2.9793675E 00	2.4350320E 01	1.0170147E 01
243000.	5.5965396E-10	1.0453582E-10	2.9835736E 00	2.4321180E 01	1.0170147E 01
244000.	5.4873389E-10	1.0223982E-10	2.9877740E 00	2.4292040E 01	1.0170147E 01
245000.	5.3805075E-10	1.0000038E-10	2.9919687E 00	2.4262900E 01	1.0170147E 01
246000.	5.2760453E-10	9.7815955E-11	2.9961577E 00	2.4233760E 01	1.0170147E 01
247000.	5.1738926E-10	9.5685037E-11	3.0003411E 00	2.4204620E 01	1.0170147E 01
248000.	5.0739933E-10	9.3606200E-11	3.0045190E 00	2.4175480E 01	1.0170147E 01
249000.	[illegible].9762924E-10	9.1578043E-11	3.0086912E 00	2.4146340E 01	1.0170147E 01
250000.	4.8807356E-10	8.9599197E-11	3.0128579E 00	2.4117200E 01	1.0170147E 01
251000.	4.7872695E-10	8.7668320E-11	3.0170190E 00	2.4088060E 01	1.0170147E 01
252000.	4.6958430E-10	8.5784129E-11	3.0211747E 00	2.4058920E 01	1.0170147E 01
253000.	4.6064073E-10	8.3945396E-11	3.0253249E 00	2.4029780E 01	1.0170147E 01
254000.	4.5189131E-10	8.2150890E-11	3.0294695E 00	2.4000640E 01	1.0170147E 01
255000.	4.4333133E-10	8.0399437E-11	3.0336088E 00	2.3971500E 01	1.0170147E 01
256000.	4.3495632E-10	7.8689916E-11	3.0377425E 00	2.3942360E 01	1.0170147E 01
257000.	4.2676160E-10	7.7021178E-11	3.0418710E 00	2.3913220E 01	1.0170147E 01
258000.	4.1874292E-10	7.5392167E-11	3.045993[illegible]E 00	2.3884080E 01	1.0170147E 01
259000.	4.1089618E-10	7.3801855E-11	3.0501116E 00	2.3854940E 01	1.0170147E 01
260000.	4.0321704E-10	7.2249190E-11	3.0542238E 00	2.3825800E 01	1.0170147E 01
261000.	3.9570171E-10	7.0733223E-11	3.0583308E 00	2.3796660E 01	1.0170147E 01
262000.	3.8834617E-10	6.9252976E-11	3.0624324E 00	2.3767520E 01	1.0170147E 01
263000.	3.8114653E-10	6.7807505E-11	3.0665288E 00	2.3738380E 01	1.0170147E 01
264000.	3.7409928E-10	6.6395932E-11	3.0706199E 00	2.3709240E 01	1.0170147E 01
265000.	3.6720071E-10	6.5017367E-11	3.0747057E 00	2.3680100E 01	1.0170147E 01
266000.	3.6044722E-10	6.3670937E-11	3.0787863E 00	2.3650960E 01	1.0170147E 01
267000.	3.5383558E-10	6.2355846E-11	3.0828618E 00	2.3621820E 01	1.0170147E 01
268000.	3.4736236E-10	6.1071270E-11	3.0869319E 00	2.3592680E 01	1.0170147E 01
269000.	3.4102430E-10	5.9816424E-11	3.0909970E 00	2.3563540E 01	1.0170147E 01
270000.	3.[illegible]481835E-10	5.8590562E-11	3.0950569E 00	2.3534400E 01	1.0170147E 01
271000.	3.2874131E-10	5.7392928E-11	3.0991116E 00	2.3505260E 01	1.0170147E 01
272000.	3.2279020E-10	[illegible].6222801E-11	3.1031613E 00	2.3476120E 01	1.0170147E 01
273000.	3.1696215E-10	[illegible].5079493E-11	3.1072059E 00	2.3446980E 01	1.0170147E 01
274000.	3.1125417E-10	5.3962300E-11	3.1112453E 00	2.3417840E 01	1.0170147E 01
275000.	3.0566371E-10	5.2870597E-11	3.1152798E 00	2.3388700E 01	1.0170147E 01
276000.	3.0018791E-10	5.1803716E-11	3.1193091E 00	2.3359560E 01	1.0170147E 01
277000.	2.9482418E-10	5.0761041E-11	3.1233335E 00	2.3330420E 01	1.0170147E 01
278000.	2.8956996E-10	4.9741963E-11	3.1273528E 00	2.3301280E 01	1.0170147E 01
279000.	2.8442274E-10	4.8745891E-11	3.1313672E 00	2.3272140E 01	1.0170147E 01
280000.	2.7938007E-10	4.7772247E-11	3.1353766E 00	2.3243000E 01	1.0170147E 01
281000.	2.7443963E-10	4.6820484E-11	3.1393811E 00	2.3213860E 01	1.0170147E 01
282000.	2.6959895E-10	4.5890033E-11	3.1433806E 00	2.3184720E 01	1.0170147E 01
283000.	2.6485591E-10	4.4980385E-11	3.1473752E 00	2.3155580E 01	1.0170147E 01
284000.	2.6020829E-10	4.4091025E-11	3.1513649E 00	2.3126440E 01	1.0170147E 01
285000.	2.5565386E-10	4.3221437E-11	3.1553498E 00	2.3097300E 01	1.0170147E 01
286000.	2.5119065E-10	4.2371158E-11	3.1593298E 00	2.3068160E 01	1.0170147E 01
287000.	2.4681647E-10	4.1539688E-11	3.1633049E 00	2.3039020E 01	1.0170147E 01
288000.	2.4252946E-10	4.0726583E-11	3.1672752E 00	2.3009880E 01	1.0170147E 01
289000.	2.3832753E-10	3.99313[illegible]9E-11	3.171[illegible]07E 00	2.2980739E 01	1.0170147E 01
290000.	2.3420896E-10	3.9153661E-11	3.1752014E 00	2.2951600E 01	1.0170147E 01
291000.	2.3017177E-10	3.8392984E-11	3.1791574E 00	2.2922460E 01	1.0170147E 01
292000.	2.26[illegible]1425E-10	3.7648951E-11	3.1831086E 00	2.2893320E 01	1.0170147E 01
293000.	2.2233453E-10	3.6921138E-11	3.1870550E 00	2.2864180E 01	1.0170147E 01
294000.	2.1853094E-10	3.6209163E-11	3.1909968E 00	2.2835039E 01	1.0170147E 01
295000.	2.1480184E-10	3.5512648E-11	3.1949338E 00	2.2805900E 01	1.0170147E 01
296000.	2.1114559E-10	3.4831222E-11	3.1988661E 00	2.2776760E 01	1.0170147E 01
297000.	2.0756057E-10	3.4164520E-11	3.2027937E 00	2.2747620E 01	1.0170147E 01
298000.	2.0404519E-10	3.3512179E-11	3.2067167E 00	2.2718480E 01	1.0170147E 01
299000.	2.0059805E-10	3.2873878E-11	3.2106351E 00	2.2689340E 01	1.0170147E 01

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE meters	PRESSURE newtons cm⁻²	KINETIC TEMPERATURE degrees K	MOLECULAR TEMPERATURE degrees K	DENSITY kg m⁻³	COEFFICIENT OF VISCOSITY newton-sec m⁻²	SPEED OF SOUND m sec⁻¹
300000.	2.0057311E-09	1.4321907E 03	1.8306500E 03	3.8168505E-11	5.8834054E-05	8.5772430E 02
302000.	1.9388602E-0.	1.4339029E 03	1.8372500E 03	3.6763428E-11	5.8952060E-05	8.5926906E 02
304000.	1.8744851E-09	1.4355909E 03	1.8438500E 03	3.5415564E-11	5.9069838E-05	8.6081107E 02
306000.	1.8125028E-09	1.4372541E 03	1.8504500E 03	3.4122362E-11	5.9187388E-05	8.6235031E 02
308000.	1.7528153E-09	1.4388925E 03	1.8570500E 03	3.2881401E-11	5.9304712E-05	8.6388681E 02
310000.	1.6953286E-09	1.440506.E 03	1.8636500E 3	3.1690368E-11	5.9421813E-05	8.6542059E 02
312000.	1.6399540E-09	1.4420949E 03	1.8702500E 03	3.0547084E-11	5.9538689E-05	8.6695164E 02
314000.	1.5866056E-09	1.4436590E 03	1.8768500E 03	2.9449450E-11	5.9655344E-05	8.684800. 02
316000.	1.5352017E-09	1.4451982E 03	1.8834500E 03	2.8395473E-11	5.9771778E-05	8.7000570 [illegible]
318000.	1.4856637E-09	1.4467126E 03	1.8900500E 03	2.7383248E-11	5.9887992E-05	8.715287[illegible] 02
320000.	1.4379174E-09	1.4482023E 03	1.8966500E 03	2.6410980E-11	6.0003988E-05	8.7304906E 02
322000.	1.3918915E-09	1.4496672E 03	1.9032500E 03	2.5476943E-11	6.0119767E-05	8.7456676E 02
324000.	1.347516[illegible]-09	1.4511072E 03	1.9098500E 03	2.4579480E-11	6.0235330E-05	8.7608185E 02
326000.	1.3047288E-09	1.4525225E 03	1.9164500E 03	2.3717042E-11	6.0350677E-05	8.7759430E 02
328000.	1.2634642E-09	1.4539130E 03	1.9230500E 03	2.2888120E-11	6.0465811E-05	8.7910416E 02
330000.	1.2236637E-09	1.4552787E 03	1.9296500E 03	2.2091301E-11	6.0580732E-05	8.8061143E 02
332000.	1.1852696E-09	1.4566196E 03	1.9362500E 03	2.1325217E-11	6.0695443E-05	8.8211613E 02
334000.	1.1482273E-09	1.4579357E 03	1.9428500E 03	2.0588579E-11	6.0809942E-05	8.8361827E 02
336000.	1.1124841E-09	1.4592270E 03	1.9494500E 03	1.9880142E-11	6.0924233E-05	8.8511784E 02
338000.	1.0779898E-09	1.4604935E 03	1.9560500E 03	1.9198728E-11	6.1038315E-05	8.8661491E 02
340000.	1.0446960E-09	1.4617353E 03	1.9626500E 03	1.8543206E-11	6.1152192E-05	8.8810942E 02
342000.	1.0125567E-09	1.4629522E 03	1.9692500E 03	1.7912503E-11	6.1265862E-05	8.8960143E 02
344000.	9.8152788E-10	1.4641444E 03	1.9758500E 03	1.7305591E-11	6.1379327E-05	8.9109095E 02
346000.	9.5156696E-10	1.4653117E 03	1.9824500E 03	1.6721486E-11	6.1492588E-05	8.9257798E 02
348000.	9.2263318E-10	1.4664543E 03	1.9890500E 03	1.6159247E-11	6.1605647E-05	8.940625[illegible] 02
350000.	8.9468797E-10	1.4675721E 03	1.9956500E 03	1.5617984E-11	6.1718505E-05	8.9554464E 02
352000.	8.6769385E-10	1.4686650E 03	2.0022500E 03	1.5096837E-11	6.1831163E-05	8.9702429E 02
354000.	8.4161512E-10	1.4697332E 03	2.0088500E 03	1.4594989E-11	6.1943621E-05	8.9850150E 02
356000.	8.1641749E-10	1.4707766E 03	2.0154500E 03	1.4111658E-11	6.2055880E-05	8.99[illegible]628E 02
358000.	7.9206777E-10	1.47179[illegible]E 03	2.0220500E 03	1.3646089E-11	6.2167941E-05	9.0144866E 02
360000.	7.6853477E-10	1.4727891E 03	2.0286500E 03	1.3197576E-11	6.2279806E-05	9.0291862E 02
362000.	7.4576808E-10	1.4737581E 03	2.0352500E 03	1.2765429E-11	6.2391474E-05	9.0438620E 02
364000.	7.2379869E-10	1.4747023E 03	2.0418500E 03	1.2348998E-11	6.2502956E-05	9.0585142E 02
366000.	7.0253869E-10	1.4756217E 03	2.0484500E 03	1.1947654E-11	6.2614238E-05	9.0731425E 02
368000.	6.8198121E-10	1.4765164E 03	2.0550500E 03	1.[illegible]E-11	6.2725328E-05	9.0877473E 02
370000.	6.6210057E-10	1.4773863E 03	2.0616500E 03	1.1187854E-11	6.2836227E-05	9.1023288E 02
372000.	6.4287257E-10	1.4782313E 03	2.0682500E 03	1.0828284E-11	6.2946935E-05	9.1168869E 02
374000.	6.2427294E-10	1.4790516E 03	2.0748500E 03	1.0481551E-11	6.3057455E-05	9.1314217E 02
376000.	6.0627922E-10	1.479847[illegible] 03	2.0814500E 03	1.0147159E-11	6.3167787E-05	9.1459335E 02
378000.	5.8886955E-10	1.4806177E 03	2.0880500E 03	9.8240245E-12	6.3277930E-05	9.1604222E 02
380000.	5.7202296E-10	1.4813637E 03	2.0946500E 03	9.5134873E-12	6.3387887E-05	9.1748883E 02
382000.	5.5571925E-10	1.4820848E 03	2.1012500E 03	9.2133057E-12	6.3497657E-05	9.1893313E 02
384000.	5.3993908E-10	1.4827811E 03	2.1078500E 03	8.9236559E-12	6.3607243E-05	9.2037518E 02
386000.	5.2466391E-10	1.4834526E 03	2.1144500E 03	8.6441346E-12	6.3716646E-05	9.2181497E 02
388000.	5.0087570E-10	1.4840993E 03	2.1210500E 03	8.3743510E-12	6.3825865E-05	9.2325252E 02
390000.	4.9555736E-10	1.4847213E 03	2.1276500E 03	8.1139344E-12	6.3934903E-05	9.2468783E 02
392000.	4.8169243E-10	1.4853184E 03	2.1342500E 03	7.8625296E-12	6.4043758E-05	9.2612091E 02
394000.	4.6826477E-10	1.4858908E 03	2.1408500E 03	7.6197901E-1.	6.4152434E-05	9.2755179E 02
396000.	4.5525939E-10	1.4864383E 03	2.1474500E 03	7.3853930E-12	6.4260931E-05	9.2898046E 02
398000.	4.4266133E-10	1.4869611E 03	2.1540500E 03	7.1590199E-12	6.4369250E-05	9.3040694E 02
400000.	4.3045664E-10	1.4874591E 03	2.1606500E 03	6.9403720E-12	6.4477389E-05	9.3183123E 02
402000.	4.1861271E-10	1.4880479E 03	2.1658500E 03	6.7332042E-12	6.4562467E-05	9.3295186E 02
404000.	4.0712851E-10	1.4886223E 03	2.1710500E 03	6.5328014E-12	6.4647434E-05	9.3407116E 02
406000.	3.9599224E-10	1.4891824E 03	2.1762500E 03	6.3389257E-12	6.4732293E-05	9.3518910E 02
408000.	3.8519245E-10	1.4897281E 03	2.1814500E 03	6.1513475E-12	6.4817043E-05	9.3630573E 02
410000.	3.7471793E-10	1.4902594E 03	2.1866500E 03	5.9698436E-12	6.4901684E-05	9.3742101E 02
412000.	3.6455822E-10	1.4907764E 03	2.1918500E 03	5.7942047E-12	6.4986220E-05	9.3853498E 02
414000.	3.5470273E-10	1.4912790E 03	2.19705[illegible]E 03	[illegible]6242236E-12	6.5070646E-05	9.3964763E 02
416000.	3.4514181E-10	1.4917673E 03	2.2022500E 03	5.459[illegible]E-12	6.5154967E-05	9.4075894E 02
418000.	3.3586559E-10	1.4922412E 03	2.2074500E 03	5.3004458E-12	6.5239180E-05	9.4186896E 02
420000.	3.2686502E-10	1.492[illegible]E 03	2.2126500E 03	5.1462808E-12	6.5323289E-05	9.4297767E 02
422000.	3.1813105E-10	1.4931459E 03	2.2178500E 03	4.9970266E-12	6.5407290E-05	9.4408507E 02
424000.	3.0365513E-10	1.4935767E 03	2.2230500E 03	4.8525140E-12	6.5491187E-05	9.4519119E 02
426000.	3.0142895E-10	1.4939931E 03	2.2282500E 03	4.7125807E-12	6.5574978E-05	9.4629600E 02
428000.	2.9344432E-10	1.4943952E 03	2.2334500E 03	4.5770667E-12	6.5658665E-05	9.4739953E 02
430000.	2.8563375E-10	1.4947829E 03	2.2386500E 03	4.4458243E-12	6.5742248E-05	9.4850178E 02
432000.	2.7816958E-10	1.4951562E 03	2.2438500E 03	4.3187053E-12	6.5825728E-05	9.4960274E 02
434000.	2.7086468E-10	1.4955153E 03	2.2490500E 03	4.1955704E-12	6.5909103E-05	9.5070243E 02
436000.	2.6377198E-10	1.4958599E 03	2.2542500E 03	4.0762832E-12	6.5992375E-05	9.5180055E 02
438000.	2.5688400E-10	1.4961901E 03	2.2594500E 03	3.9607135E-12	6.6075546E-05	9.5289800E 02

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE meters	PRESSURE RATIO unitless	DENSITY RATIO unitless	VISCOSITY RATIO unitless	MOLECULAR WEIGHT unitless	PRESSURE DIFFERENCE newtons cm^{-2}
300000.	1.9721751E-10	3.2249259E-11	3.2145488E 00	2.2660000E 01	1.0170147E 01
302000.	1.9064230E-10	3.1062084E-11	3.2209964E 00	2.2605600E 01	1.0170147E 01
304000.	1.8431249E-10	2.9923249E-11	3.2274314E 00	2.2551200E 01	1.0170147E 01
306000.	1.7821795E-10	2.8830599E-11	3.2338541E 00	2.2496800E 01	1.0170147E 01
308000.	1.7234906E-10	2.7782089E-11	3.2402644E 00	2.2442400E 01	1.0170147E 01
310000.	1.6669656E-10	2.6775764E-11	3.2466625E 00	2.2388000E 01	1.0170147E 01
312000.	1.6125175E-10	2.5809783E-11	3.2530483E 00	2.2333600E 01	1.0170147E 01
314000.	1.5600616E-10	2.4882371E-11	3.2594221E 00	2.2279200E 01	1.0170147E 01
316000.	1.5095177E-10	2.3991847E-11	3.2657837E 00	2.2224800E 01	1.0170147E 01
318000.	1.4608084E-10	2.3136601E-11	3.2721334E 00	2.2170400E 01	1.0170147E 01
320000.	1.4138610E-10	2.2315113E-11	3.2784711E 00	2.2116000E 01	1.0170147E 01
322000.	1.3686051E-10	2.1525929E-11	3.2847970E 00	2.2061600E 01	1.0170147E 01
324000.	1.3249728E-10	2.0767646E-11	3.2911111E 00	2.2007200E 01	1.0170147E 01
326000.	1.2829006E-10	2.0038957E-11	3.2974133E 00	2.1952800E 01	1.0170147E 01
328000.	1.2423264E-10	1.9338586E-11	3.3037040E 00	2.1898400E 01	1.0170147E 01
330000.	1.2031917E-10	1.8665339E-11	3.3099830E 00	2.1844000E 01	1.0170147E 01
332000.	1.1654399E-10	1.8018061E-11	3.3162505E 00	2.1789600E 01	1.0170147E 01
334000.	1.1290174E-10	1.7395662E-11	3.3225065E 00	2.1735200E 01	1.0170147E 01
336000.	1.0938722E-10	1.6797091E-11	3.3287511E 00	2.1680800E 01	1.0170147E 01
338000.	1.0599549E-10	1.6221351E-11	3.3349842E 00	2.1626400E 01	1.0170147E 01
340000.	1.0272181E-10	1.5667489E-11	3.3412062E 00	2.1572000E 01	1.0170147E 01
342000.	9.9561659E-11	1.5134597E-11	3.3474168E 00	2.1517600E 01	1.0170147E 01
344000.	9.6510686E-11	1.4621806E-11	3.3536163E 00	2.1463200E 01	1.0170147E 01
346000.	9.3564718E-11	1.4128285E-11	3.3598046E 00	2.1408800E 01	1.0170147E 01
348000.	9.0719748E-11	1.3653240E-11	3.3659819E 00	2.1354400E 01	1.0170147E 01
350000.	8.7971978E-11	1.3195917E-11	3.3721481E 00	2.1300000E 01	1.0170147E 01
352000.	8.5317729E-11	1.2755590E-11	3.3783035E 00	2.1245600E 01	1.0170147E 01
354000.	8.2753484E-11	1.2331570E-11	3.3844479E 00	2.1191200E 01	1.0170147E 01
356000.	8.0275878E-11	1.1923194E-11	3.3905815E 00	2.1136800E 01	1.0170147E 01
358000.	7.7881643E-11	1.1529827E-11	3.3967043E 00	2.1082400E 01	1.0170147E 01
360000.	7.5567713E-11	1.1150870E-11	3.4028164E 00	2.1028000E 01	1.0170147E 01
362000.	7.3331100E-11	1.0785742E-11	3.4089178E 00	2.0973600E 01	1.0170147E 01
364000.	7.1168948E-11	1.0433891E-11	3.4150086E 00	2.0919200E 01	1.0170147E 01
366000.	6.9078517E-11	1.0094788E-11	3.4210888E 00	2.0864800E 01	1.0170147E 01
368000.	6.7057161E-11	9.7679259E-12	3.4271585E 00	2.0810400E 01	1.0170147E 01
370000.	6.5102358E-11	9.4528193E-12	3.4332178E 00	2.0756000E 01	1.0170147E 01
372000.	6.3211727E-11	9.1490122E-12	3.4392665E 00	2.0701600E 01	1.0170147E 01
374000.	6.1382881E-11	8.8560518E-12	3.4453051E 00	2.0647200E 01	1.0170147E 01
376000.	5.9613612E-11	8.5735176E-12	3.4513333E 00	2.0592800E 01	1.0170147E 01
378000.	5.7901772E-11	8.3010025E-12	3.4573513E 00	2.0538400E 01	1.0170147E 01
380000.	5.6245297E-11	8.0381171E-12	3.4633591E 00	2.0484000E 01	1.0170147E 01
382000.	5.4642204E-11	7.7844882E-12	3.4693566E 00	2.0429600E 01	1.0170147E 01
384000.	5.3090586E-11	7.5397579E-12	3.4753442E 00	2.0375200E 01	1.0170147E 01
386000.	5.1588625E-11	7.3035854E-12	3.4813217E 00	2.0320800E 01	1.0170147E 01
388000.	5.0134544E-11	7.0756403E-12	3.4872891E 00	2.0266400E 01	1.0170147E 01
390000.	4.8726665E-11	6.8556096E-12	3.4932467E 00	2.0212000E 01	1.0170147E 01
392000.	4.7363369E-11	6.6431931E-12	3.4991943E 00	2.0157600E 01	1.0170147E 01
394000.	4.6043067E-11	6.4380981E-12	3.5051321E 00	2.0103200E 01	1.0170147E 01
396000.	4.4764287E-11	6.2400517E-12	3.5110601E 00	2.0048800E 01	1.0170147E 01
398000.	4.3525558E-11	6.0487851E-12	3.5169784E 00	1.9994400E 01	1.0170147E 01
400000.	4.2325508E-11	5.8640456E-12	3.5228868E 00	1.9940000E 01	1.0170147E 01
402000.	4.1160929E-11	5.6890058E-12	3.5275352E 00	1.9900000E 01	1.0170147E 01
404000.	4.0031723E-11	5.5196818E-12	3.5321777E 00	1.9860000E 01	1.0170147E 01
406000.	3.8936727E-11	5.3558727E-12	3.5368142E 00	1.9820000E 01	1.0170147E 01
408000.	3.7874815E-11	5.1973845E-12	3.5414447E 00	1.9780000E 01	1.0170147E 01
410000.	3.6844887E-11	5.0440286E-12	3.5460694E 00	1.9740000E 01	1.0170147E 01
412000.	3.5845914E-11	4.8956280E-12	3.5506881E 00	1.9700000E 01	1.0170147E 01
414000.	3.4876853E-11	4.7520055E-12	3.5553010E 00	1.9660000E 01	1.0170147E 01
416000.	3.3936757E-11	4.6129984E-12	3.5599080E 00	1.9620000E 01	1.0170147E 01
418000.	3.3024653E-11	4.4784423E-12	3.5645092E 00	1.9580000E 01	1.0170147E 01
420000.	3.2139654E-11	4.3481855E-12	3.5691047E 00	1.9540000E 01	1.0170147E 01
422000.	3.1280870E-11	4.2220779E-12	3.5736943E 00	1.9500000E 01	1.0170147E 01
424000.	3.0447457E-11	4.0999767E-12	3.5782783E 00	1.9460000E 01	1.0170147E 01
426000.	2.9638602E-11	3.9817445E-12	3.5828564E 00	1.9420000E 01	1.0170147E 01
428000.	2.8853498E-11	3.8672462E-12	3.5874288E 00	1.9380000E 01	1.0170147E 01
430000.	2.8091408E-11	3.7563572E-12	3.5919957E 00	1.9340000E 01	1.0170147E 01
432000.	2.7351578E-11	3.6489520E-12	3.5965567E 00	1.9300000E 01	1.0170147E 01
434000.	2.6633309E-11	3.5449132E-12	3.6011122E 00	1.9260000E 01	1.0170147E 01
436000.	2.5935906E-11	3.4441252E-12	3.6056620E 00	1.9220000E 01	1.0170147E 01
438000.	2.5258710E-11	3.3464783E-12	3.6102062E 00	1.9180000E 01	1.0170147E 01

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14. 9 (Continued)

GEOMETRIC ALTITUDE	PRESSURE	KINETIC TEMPERATURE	MOLECULAR TEMPERATURE	DENSITY	COEFFICIENT OF VISCOSITY	SPEED OF SOUND
meters	newtons cm^{-2}	degrees K	degrees K	kg m^{-3}	newton-sec m^{-2}	m sec^{-1}
440000.	2.5019664E-10	1.4965061E 03	2.2646500E 03	3.8487362E-12	6.6158612E-05	9.5399390E 02
442000	2.4370127E-10	1.4968076E 03	2.2698500E 03	3.7402308E-12	6.6241579E-05	9.5508853E 02
444000.	2.3739258E-10	1.4970948E 03	2.2750500E 03	3.6350798E-12	6.6324444E-05	9.5618191E 02
446000.	2.3126473E-10	1.4973676E 03	2.2802500E 03	3.5331714E-12	6.6407207E-05	9.5727403E 02
448000.	2.2531199E-10	1.4976261E 03	2.2854500E 03	3.4343957E-12	6.6489869E-05	9.5836493E 02
450000.	2.1952890E-10	1.4978702E 03	2.2906500E 03	3.3386486E-12	6.6572431E-05	9.5945457E 02
452000.	2.1391031E-10	1.4980998E 03	2.2958500E 03	3.2458315E-12	6.6654892E-05	9.6054298E 02
454000.	2.0845093E-10	1.4963152E 03	2.3010500E 03	3.15584[illegible]1E-12	6.6737255E-05	9.6163017E 02
456000.	2.0314599E-10	1.4985162E 03	2.3062500E 03	3.0685954E-12	6.6819517E-05	9.6271610E 02
458000.	1.9799060E-10	1.4987029E 03	2.3114500E 03	2.9839931E-12	6.6901681E-05	9.6380085E 02
460000.	1.9298021E-10	1.4988752E 03	2.3166500E 03	2.9019512E-12	6.6983746E-05	9.6488435E 02
462000.	1.8811034E-10	1.4990331E 03	2.3218500E 03	2.8223851E-12	6.7065712E-05	9.6596664E 02
464000.	1.8337669E-10	1.4991767E [illegible]	2.3270500E 03	2.7452138E-12	6.7147580E-05	9.6704772E 02
466000.	1.7877516E-10	1.4993058E 03	2.3322500E 03	2.6703602E-12	6.7229351E-05	9.6812760E 02
468000.	1.7430157E-10	1.4994207E 03	2.3374500E 03	2.5977463E-12	6.7311026E-05	9.6920626E 02
470000.	1.6995216E-10	1.4995212E 03	2.3426500E 03	2.5273014E-12	6.7392603E-05	9.7028373E 02
472000.	1.6572313E-10	1.4996073E 03	2.3478500E 03	2.4589548E-12	6.7474083E-05	9.713[illegible]902E 02
474000.	1.6161082E-10	1.4996790E 03	2.3530500E 03	2.3926382E-12	6.7555466E-05	9.7245[illegible]10E 02
476000.	1.5761171E-10	1.4997363E 03	2.3582500E 03	2.3282864E-12	6.7636753E-05	9.7350900E 02
478000.	1.5372238E-10	1.4997794E 03	2.3634500E 03	2.2658358E-12	6.7717947E-05	9.7458172E 02
480000.	1.4993956E-10	1.4998080E 03	2.3686500E 03	2.2052260E-12	6.7799044E-05	9.7565325E 02
482000.	1.4626006E-10	1.4998223E 03	2.3738500E 03	2.1463978E-12	6.7880046E-05	9.7672361E 02
484000.	1.4268077E-10	1.4998223E 03	2.3790500E 03	2.0892944E-12	6.7960953E-05	9.7779280E 02
486000.	1.3919874E-10	1.4998078E 03	2.3842500E 03	2.0338610E-12	6.8041767E-05	9.7886081E 02
488000.	1.35811[illegible]1E-10	1.4997790E 03	2.3894500E 03	1.9800438E-12	6.8122485E-05	9.7992767E 02
490000.	1.3251436E-10	1.4997359E 03	2.3946500E 03	1.9277925E-12	6.8203111E-05	9.8099338E 02
492000.	1.2930755E-10	1.4996784E 03	2.3998500E 03	1.8770573E-12	6.8283644E-05	9.8205791E 02
494000.	1.2618645E-10	1.4996065E 03	2.4050500E 03	1.8277902E-12	6.8364083E-05	9.8312130E 02
496000.	1.2314902E-10	1.4995202E 03	2.4102500E 03	1.7799451E-12	6.8444428E-05	9.8418353E 02
498000.	1.2019283E-10	1.4994196E 03	2.4154500E 03	1.7334778E-12	6.8524683E-05	9.8524462E 02
500000.	1.1731545E-10	1.4993047E 03	2.4206500E 03	1.6883441E-12	6.8604845E-05	9.8630458E 02
502000.	1.1451121E-10	1.4995694E 03	2.4240500E 03	1.6456754E-12	6.8657209E-05	9.8699701E 02
504000.	1.1177938E-10	1.4998289E 03	2.4274500E 03	1.6041654E-12	6.8709534E-05	9.8768895E 02
506000.	1.0911792E-10	1.5000833E 03	2.4308500E 03	1.5637801E-12	6.8761820E-05	9.8838041E 02
508000.	1.0652497E-10	1.5003325E 03	2.4342500E 03	1.5244880E-12	6.8814067E-05	9.8907138E 02
510000.	1.0399854E-10	1.5005765E 03	2.4376500E 03	1.4862561E-12	6.8866274E-05	9.8976188E 02
512000.	1.0153685E-10	1.5008154E 03	2.4410500E 03	1.4490546E-12	6.8918[illegible]44E-05	9.9045190E 02
514000.	9.9138149E-11	1.5010491E 03	2.4444500E 03	1.4128544E-12	6.8970575E-05	9.9114143E 02
516000.	9.6800666E-11	1.5012776E 03	2.4478500E 03	1.3776259E-12	6.9022667E-05	9.9183048E 02
518000.	9.4522758E-11	1.5015010E 03	2.4512500E 03	1.3433418E-12	6.9074719E-05	9.9251904E 02
520000.	9.2302788E-11	1.5017193E 03	2.4546500E 03	1.3099750E-12	6.9126735E-05	9.9320714E 02
522000.	9.0139147E-11	1.5019323E 03	2.4580500E 03	1.2774988E-12	6.9178711E-05	9.9389477E 02
524000.	8.8030359E-11	1.5021402E 03	2.4614500E 03	1.2458886E-12	6.9230649E-05	9.9458191E 02
526000.	8.5974921E-11	1.5023429E 03	2.4648500E 03	1.2151197E-12	6.9282550E-05	9.9526858E 02
528000.	8.3971362E-11	1.5025405E 03	2.4682500E 03	1.18516[illegible]-12	6.9334410E-05	9.9595479E 02
530000.	8.2018286E-11	1.5027328E 03	2.4716499E 03	1.1560097E-12	6.9386234E-05	9.9664050E 02
532000.	8.0114324E-11	1.5029201E 03	2.4750500E 03	1.1276231E-12	6.9438021E-05	9.9732577E 02
534000.	7.8258179E-11	1.5031021E 03	2.4784500E 03	1.0999864E-12	6.9489769E-05	9.9801055E 02
536000.	7.6448556E-11	1.5032790E 03	2.4818500E 03	1.0730785E-12	6.9541479E-05	9.9869486E 02
538000.	7.4684181E-11	1.5034507E 03	2.4852500E 03	1.0468785E-12	6.9593151E-05	9.9937871E 02
540000.	7.2963864E-11	1.5036173E 03	2.4886500E 03	1.0213668E-12	6.9644787E-05	1.0000621E 03
542000.	7.128[illegible]404E-11	1.5037787E 03	2.4920500E 03	9.9652387E-13	6.9696384E-05	1.0007450E 03
544000.	6.9650681E-11	1.5039350E 03	2.4954500E 03	9.7233125E-13	6.9747944E-05	1.0014274E 03
546000.	6.8055573E-11	1.5040860E 03	2.4988500E 03	9.4877069E-13	6.9799466E-05	1.0021094E 03
548000.	6.6500008E-11	1.5042319E 03	2.5022500E 03	9.2582468E-13	6.9850951E-05	1.0027909E 03
550000.	6.4982911E-11	1.5043727E 03	2.5056500E 03	9.0347577E-13	6.9902399E-05	1.0034720E 03
552000.	6.3503272E-11	1.5045083E 03	2.5090500E 03	8.8170750E-13	6.9953810E-05	1.0041526E 03
554000.	6.2060105E-11	1.5046387E 03	2.5124500E 03	8.6050388E-13	7.0005184E-05	1.0048327E 03
556000.	6.0652455E-11	1.5047639E 03	2.5158500E 03	8.3984936E-13	7.0056520E-05	1.0055124E 03
558000.	5.9279361E-11	1.5048840E 03	2.5192500E 03	8.1972843E-13	7.0107821E-05	1.0061916E 03
560000.	5.7939934E-11	1.5049989E 03	2.5226499E 03	8.0012667E-13	7.0159083E-05	1.0068703E 03
562000.	5.6633257E-11	1.5051087E 03	2.5260500E 03	7.8102934E-13	7.0210310E-05	1.0075486E 03
564000.	5.5358504E-11	1.5052133E 03	2.5294500E 03	7.6242301E-13	7.0261499E-05	1.0082265E 03
566000.	5.4114844E-11	1.5053127E 03	2.5328500E 03	7.4429430E-13	7.0312652E-05	1.0089039E 03
568000.	5.2901430E-11	1.5054069E 03	2.5362500E 03	7.2662964E-13	7.0363768E-05	1.0095808E 03
570000.	5.1717495E-11	1.5054960E 03	2.5396500E 03	7.0941664E-13	7.0414849E-05	1.0102573E 03
572000.	5.0562249E-11	1.5055800E 03	2.5430500E 03	6.9264266E-13	7.0465892E-05	1.0109333E 03
574000.	4.9434978E-11	1.5056587E 03	2.5464500E 03	6.7629619E-13	7.0516899E-05	1.0116089E 03
576000.	4.8334925E-11	1.5057323E 03	2.5498500E 03	6.6036518E-13	7.0567870E-05	1.0122840E 03
578000.	4.7261423E-11	1.5058008E 03	2.5532500E 03	6.4483888E-13	7.0618805E-05	1.0129586E 03

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE	PRESSURE RATIO	DENSITY RATIO	VISCOSITY RATIO	MOLECULAR WEIGHT	PRESSURE DIFFERENCE
meters	unitless	unitless	unitless	unitless	newtons cm^{-2}
440000.	2.4601083E-11	3.2518666E-12	3.6147448E 00	1.9140000E 01	1.0170147E 01
442000.	2.3962413E-11	3.1601885E-12	3.6192779E 00	1.9100000E 01	1.0170147E 01
444000.	2.3342098E-11	3.0713445 -12	3.6238054E 00	1.9060000E 01	1.0170147E 01
446000.	2.2739566E-11	2.9852403E-12	3.6283273E 00	1.9020000E 01	1.0170147E 01
448000.	2.2154250E-11	2.9017829E-12	3.6328438E 00	1.8980000E 01	1.0170147E 01
450000.	2.1585616E-11	2.8208845E-12	3.6373548E 00	1.8940000E 01	1.0170147E 01
452000.	2.1033157E-11	2.7424616E-12	3.6418602E 00	1.8900000E 01	1.0170147E 01
454000.	2.0496353E-11	2.6664296E-12	3.6463604E 00	1.8860000E 01	1.0170147E 01
456000.	1.9974735E-11	2.5927117E-12	3.6508549E 00	1.8820000E 01	1.0170147E 01
458000.	1.9467820E-11	2.5212297E-12	3.6553442E 00	1.8780000E 01	1.0170147E 01
460000.	1.8975164E-11	2.4519109E-12	3.6598280E 00	1.8740000E 01	1.0170147E 01
462000.	1.8496324E-11	2.3846841E-12	3.6643064E 00	1.8700000E 01	1.0170147E 01
464000.	1.8030879E-11	2.3194807E-12	3.6687796E 00	1.8660000E 01	1.0170147E 01
466000.	1.7578424E-11	2.2562355E-12	3.6732473E 00	1.8620000E 01	1.0170147E 01
468000.	1.7138550E-11	2.1948827E-12	3.6777098E 00	1.8580000E 01	1.0170147E 01
470000.	1.6710885E-11	2.1353625E-12	3.6821670E 00	1.8540000E 01	1.0170147E 01
472000.	1.6295057E-11	2.0776153E-12	3.6866188E 00	1.8500000E 01	1.0170147E 01
474000.	1.5890706E-1[illegible]	[illegible].0215832E-12	3.6910654E 00	1.8460000E 01	1.0170147E 01
476000.	1.5497486E-[illegible]	[illegible]9672112E-12	3.6955068E 00	1.8420000E 01	1.0170147E 01
478000.	1.5115059E-[illegible]	[illegible]9144435E-12	3.6999429E 00	1.8380000E 01	1.0170147E 01
480000.	1.4743106E-11	1.8632352E-12	3.7043739E 00	1.8340000E 01	1.0170147E 01
482000.	1.4381312E-11	1.8135305E-12	3.7087997E 00	1.8300000E 01	1.0170147E 01
484000.	1.4029371E-11	1.7652825E-12	3.7132202E 00	1.8260000E 01	1.0170147E 01
486000.	1.3686994E-11	1.7184459E-12	3.7176357E 00	1.8220000E 01	1.0170147E 01
488000.	1.3353888E-11	1.6729747E-12	3.7220460E 00	1.8180000E 01	1.0170147E 01
490000.	1.3029787E-11	1.6288266E-12	3.7264512E 00	1.8140000E 01	1.0170147E 01
492000.	1.2714423E-11	1.5859596E-12	3.7308513E 00	1.8100000E 01	1.0170147E 01
494000.	1.2407534E-11	1.5443330E-12	3.7352462E 00	1.8060000E 01	1.0170147E 01
496000.	1.2108872E-11	1.5039077E-12	3.7396361E 00	1.8020000E 01	1.0170147E 01
498000.	1.1818200E-11	1.4646467E-12	3.7440211E 00	1.7980000E 01	1.0170147E 01
500000.	1.1535275E-11	1.4265124E-12	3.7484009E 00	1.7940000E 01	1.0170147E 01
502000.	1.1259543E-11	1.3904608E-12	3.7512619E 00	1.7918000E 01	1.0170147E 01
504000.	1.0990930E-11	1.3553883E-12	3.7541209E 00	1.7896000E 01	1.0170147E 01
506000.	1.0729237E-11	1.3212660E-12	3.7569776E 00	1.7874000E 01	1.0170147E 01
508000.	1.0474280E-11	1.2880674E-12	3.7598323E 00	1.7852000E 01	1.0170147E 01
510000.	1.0225864E-11	1.2557646E-12	3.7626848E 00	1.7830000E 01	1.0170147E 01
512000.	9.9838128E-12	1.2243324E-12	3.7655352E 00	1.7808000E 01	1.0170147E 01
514000.	9.7479562E-12	1.1937462E-12	3.7683835E 00	1.7786000E 01	1.0170147E 01
516000.	9.5181185E-12	1.1639810E-12	3.7712297E 00	1.7764000E 01	1.0170147E 01
518000.	9.2941386E-12	1.1350137E-12	3.7740737E 00	1.7742000E 01	1.0170147E 01
520000.	9.0758557E-12	1.1068215E-12	3.7769157E 00	1.7720000E 01	1.0170147E 01
522000.	8.8631114E-12	1.0793818E-12	3.7797555E 00	1.7698000E 01	1.0170147E 01
524000.	8.6557605E-12	1.0526737E-12	3.7825933E 00	1.7676000E 01	1.0170147E 01
526000.	8.4536555E-12	1.0266765E-12	3.7854290E 00	1.7654000E 01	1.0170147E 01
528000.	8.2566516E-12	1.0013696E-12	3.7882626E 00	1.7632000E 01	1.0170147E 01
530000.	8.0646114E-12	9.7673345E-13	3.7910941E 00	1.7610000E 01	1.0170147E 01
532000.	7.8774006E-12	9.5274907E-13	3.7939236E 00	1.7588000E 01	1.0170147E 01
534000.	7.6948915E-12	9.2939839E-13	3.7967510E 00	1.7566000E 01	1.0170147E 01
536000.	7.5169567E-12	9.0666342E-13	3.7995763E 00	1.7544000E 01	1.0170147E 01
538000.	7.3434709E-12	8.8452656E-13	3.8023995E 00	1.7522000E 01	1.0170147E 01
540000.	7.1743174E-12	8.6297128E-13	3.8052208E 00	1.7500000E 01	1.0170147E 01
542000.	7.0093778E-12	8.4198101E-13	3.8080399E 00	1.7478000E 01	1.0170147E 01
544000.	6.8485421E-12	8.2154022E-13	3.8108571E 00	1.7456000E 01	1.0170147E 01
546000.	6.6916999E-12	8.0163348E-13	3.8136721E 00	1.7434000E 01	1.0170147E 01
548000.	6.5387459E-12	7.8224598E-13	3.8164851E 00	1.7412000E 01	1.0170147E 01
550000.	6.3895743E-12	7.6336299E-13	3.8192961E 00	1.7390000E 01	1.0170147E 01
552000.	6.2440858E-12	7.4497059E-13	3.8221051E 00	1.7368000E 01	1.0170147E 01
554000.	6.1021836E-12	7.2705526E-13	3.8249120E 00	1.7346000E 01	1.0170147E 01
556000.	5.9637735E-12	7.0960388E-13	3.8277169E 00	1.7324000E 01	1.0170147E 01
558000.	5.8287613E-12	6.9260335E-13	3.8305198E 00	1.7302000E 01	1.0170147E 01
560000.	5.6970595E-12	6.7604147E-13	3.8333207E 00	1.7280000E 01	1.0170147E 01
562000.	5.5685779E-12	6.5990578E-13	3.8361196E 00	1.7258000E 01	1.0170147E 01
564000.	5.4432353E-12	6.4418496E-13	3.8389165E 00	1.7236000E 01	1.0170147E 01
566000.	5.3209499E-12	6.2886768E-13	3.8417113E 00	1.7214000E 01	1.0170147E 01
568000.	5.2016386E-12	6.1394249E-13	3.8445041E 00	1.7192000E 01	1.0170147E 01
570000.	5.0852258E-12	5.9939892E-13	3.8472950E 00	1.7170000E 01	1.0170147E 01
572000.	4.9716340E-12	5.8522629E-13	3.8500840E 00	1.7148000E 01	1.0170147E 01
574000.	4.8607928E-12	5.7141486E-13	3.8528709E 00	1.7126000E 01	1.0170147E 01
576000.	4.7526278E-12	5.5795445E-13	3.8556558E 00	[illegible]7104000E 01	1.0170147E 01
578000.	4.6470737E-12	5.4483600E-13	3.8584388E 00	1.7082000E 01	1.0170147E 01

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE meters	PRESSURE newtons cm^{-2}	KINETIC TEMPERATURE degrees K	MOLECULAR TEMPERATURE degrees K	DENSITY kg m^{-3}	COEFFICIENT OF VISCOSITY newton-sec m^{-2}	SPEED OF SOUND m sec^{-1}
580000.	4.6213737E-11	1.5058640E 03	2.5566500E 03	6.2970561E-13	7.0669703E-05	1.0136329E 03
582000.	4.5191225E-11	1.5059221E 03	2.5600500E 03	6.1495511E-13	7.0720567E-05	1.0143067E 03
584000.	4.4193244E-11	1.5059751E 03	2.5634500E 03	6.0057713E-13	7.0771394E-05	1.0149800E 03
586000.	4.3219147E-11	1.5060228E 03	2.5668500E 03	5.8656136E-13	7.0822185E-05	1.0156529E 03
588000.	4.2268324E-11	1.5060654E 03	2.5702500E 03	5.7289814E-13	7.0872940E-05	1.0163253E 03
590000.	4.1340184E-11	1.5061029E 03	2.5736500E 03	5.5957806E-13	7.0923660E-05	1.0169973E 03
592000.	4.0434149E-11	1.5061352E 03	2.5770500E 03	5.4659193E-13	7.0974344E-05	1.0176688E 03
594000.	3.9549641E-11	1.5061623E 03	2.5804500E 03	5.3393065E-13	7.1024992E-05	1.0183399E 03
596000.	3.8686114E-11	1.5061842E 03	2.5838500E 03	5.2158557E-13	7.1075606E-05	1.0190106E 03
598000.	3.7843038E-11	1.5062010E 03	2.5872500E 03	5.0954831E-13	7.1126183E-05	1.0196808E 03
600000.	3.7019889E-11	1.5062126E 03	2.5906500E 03	4.9781058E-13	7.1176726E-05	1.0203506E 03
602000.	3.6215577E-11	1.5062921E 03	2.5928500E 03	4.8658169E-13	7.1209410E-05	1.0207837E 03
604000.	3.5429846E-11	1.506369.E 03	[illegible]950500E 03	4.7562129E-13	7.1242081E-05	1.0212167E 03
606000.	3.4662245E-11	1.5064451E 03	2.5972500E 03	4.6492264E-13	7.1274736E-05	1.0216495E 03
608000.	3.3912334E-11	1.5065186E 03	2.5994500E 03	4.5447915E-13	7.1307377E-05	1.0220821E 03
610000.	3.3179683E-11	1.5065899E 03	2.6016500E 03	4.4428445E-13	7.1340003E-05	1.0225145E 03
612000.	3.2463859E-11	1.5066593E 03	2.6038500E 03	4.3433210E-13	7.1372615E-05	1.0229468E 03
614000.	3.1764455E-11	1.5067267E 03	2.6060500E 03	4.2461606E-13	7.1405212E-05	1.0233788E 03
616000.	3.1081098E-11	1.5067919E 03	2.6082500E 03	4.1513073E-13	7.1437795E-05	1.0238107E 03
618000.	3.0413369E-11	1.5068552E 03	2.6104500E 03	4.0586995E-13	7.1470361E-05	1.0242424E 03
620000.	2.9760908E-11	1.5069164E 03	2.6126499E 03	3.9682836E-13	7.1502915E-05	1.0246739E 03
622000.	2.9123341E-11	1.5069756E 03	2.6148500E 03	3.9800040E-13	7.1535454E-05	1.0251052E 03
624000.	2.8500294E-11	1.5070327E 03	2.6170500E 03	3.7938056E-13	7.1567978E-05	1.0255363E 03
626000.	2.7891442E-11	1.5070878E 03	2.6192500E 03	3.7096400E-13	7.1600487E-05	1.0259673E 03
628000.	2.7296429E-11	1.5071409E 03	2.6214500E 03	3.6274548E-13	7.1632982E-05	1.0263981E 03
630000.	2.6714925E-11	1.5071919E 03	2.6236500E 03	3.5472012E-13	7.1665463E-05	1.0268287E 03
632000.	2.6146607E-11	1.5072410E 03	2.6258500E 03	3.4688313E-13	7.1697928E-05	1.0272591E 03
634000.	2.5591154E-11	1.5072879E 03	2.6280500E 03	3.3922980E-13	7.1730380E-05	1.0276894E 03
636000.	2.5048265E-11	1.5073328E 03	2.6302500E 03	3.3175568E-13	7.1762818E-05	1.0281194E 03
638000.	2.4517629E-11	1.5073758E 03	2.6324500E 03	3.2445621E-13	7.1795239E-05	1.0285493E 03
640000.	2.3998967E-11	1.5074166E 03	2.6346500E 03	3.1732726E-13	7.1827648E-05	1.0289790E 03
642000.	2.3491985E-11	1.5074555E 03	2.6368500E 03	3.1036448E-13	7.1860043E-05	1.0294085E 03
644000.	2.2996400E-11	1.5074923E 03	2.6390500E 03	3.0356381E-13	7.1892422E-05	1.0298379E 03
646000.	2.2511953E-11	1.5075270E 03	2.6412500E 03	2.9692135E-13	7.1924787E-05	1.0302670E 03
648000.	2.2038369E-11	1.5075597E 03	2.6434500E 03	2.9043309E-13	7.1957139E-05	1.0306960E 03
650000.	2.1575395E-11	1.5075904E 03	2.6456500E 03	2.8409535E-13	7.1989475E-05	1.0311248E 03
652000.	2.1122777E-11	1.5076191E 03	2.6478500E 03	2.7790439E-13	7.2021797E-05	1.0315534E 03
654000.	2.0680276E-11	1.5076457E 03	2.6500500E 03	2.7185668E-13	7.2054106E-05	1.0319819E 03
656000.	2.0247647E-11	1.5076703E 03	2.6522500E 03	2.6594870E-13	7.2086399E-05	1.0324102E 03
658000.	1.9824656E-11	1.5076928E 03	2.6544500E 03	2.6017698E-13	7.2118679E-05	1.0328383E 03
660000.	1.9411084E-11	1.5077133E 03	2.6566499E 03	2.5453834E-13	7.2150944E-05	1.0332662E 03
662000.	1.9006698E-11	1.5077318E 03	2.6588500E 03	2.4902938E-13	7.2183195E-05	1.0336939E 03
664000.	1.8611281E-11	1.5077482E 03	2.6610500E 03	2.4364696E-13	7.2215433E-05	1.0341215E 03
666000.	1.822[illegible]E-11	1.5077626E 03	2.6632500E 03	2.3833819E-13	7.2247656E-05	1.0345489E 03
668000.	1.784[illegible]47E-11	1.5077750E 03	2.6654500E 03	2.3324987E-13	7.2279864E-05	1.0349761E 03
670000.	1.7476821E-11	1.5077853E 03	2.6676500E 03	2.2822927E-13	7.2312059E-05	1.0354031E 03
672000.	1.7115252E-11	1.5077936E 03	2.6698500E 03	2.2332338E-13	7.2344239E-05	1.0358300E 03
674000.	1.6761651E-11	1.5077999E 03	2.6720500E 03	2.1852944E-13	7.2376407E-05	1.0362567E 03
676000.	1.6415844E-11	1.5078041E 03	2.6742500E 03	2.1384493E-13	7.2408558E-05	1.0366832E 03
678000.	1.6077632E-11	1.5078063E 03	2.6764500E 03	2.0926697E-13	7.2440697E-05	1.0371095E 03
680000.	1.5746857E-11	1.5078064E 03	2.6786500E 03	2.0479326E-13	7.2472821E-05	1.0375357E 03
682000.	1.5423325E-11	1.5078045E 03	2.6808500E 03	2.0042101E-13	7.2504931E-05	1.0379616E 03
684000.	1.5106879E-11	1.5078006E 03	2.6830500E 03	1.9614794E-13	7.2537029E-05	1.0383874E 03
686000.	1.4797364E-11	1.5077946E 03	2.6852500E 03	1.9197178E-13	7.2569111E-05	1.0388131E 03
688000.	1.4494605E-11	1.5077867E 03	2.6874500E 03	1.8789003E-13	7.2601179E-05	1.0392385E 03
690000.	1.4198453E-11	1.5077766E 03	2.6896500E 03	1.8390054E-13	7.2633234E-05	1.0396638E 03
692000.	1.3908750E-11	1.5077646E 03	2.6918500E 03	1.8000104E-13	7.2665275E-05	1.0400889E 03
694000.	1.3625348E-11	1.5077505E 03	2.6940500E 03	1.7618937E-13	7.2697302E-05	1.0405139E 03
696000.	1.3348109E-11	1.5077343E 03	2.6962500E 03	1.7246356E-13	7.2729314E-05	1.0409386E 03
698000.	1.3076882E-11	1.5077162E 03	2.6984500E 03	1.6882143E-13	7.2761313E-05	1.0413632E 03
700000.	1.2811533E-11	1.5076960E 03	2.7006500E 03	1.6526106E-13	7.2793300E-05	1.0417877E 03

CAPE KENNEDY REFERENCE ATMOSPHERE VERSUS GEOMETRIC ALTITUDE (ANNUAL)

Table 14.9 (Continued)

GEOMETRIC ALTITUDE	PRESSURE RATIO	DENSITY RATIO	VISCOSITY RATIO	MOLECULAR WEIGHT	PRESSURE DIFFERENCE
meters	unitless	unitless	unitless	unitless	newtons cm^{-2}
580000.	4.5440578E-12	5.3204963E-13	3.8612197E 00	1.7060000E 01	1.0170147E 01
582000.	4.4435173E-12	5.1958667E-13	3.8639588E 00	1.7038000E 01	1.0170147E 01
584000.	4.3453886E-12	5.0743845E-13	3.8667759E 00	1.7016000E 01	1.0170147E 01
586000.	4.2496088E-12	4.9559628E-13	3.8695509E 00	1.6994000E 01	1.0170147E 01
588000.	4.1561172E-12	4.8405197E-13	3.8723241E 00	1.6972000E 01	1.0170147E 01
590000.	4.0648560E-12	4.7279759E-13	3.8750953E 00	1.6950000E 01	1.0170147E 01
592000.	3.9757683E-12	4.6182538E-13	3.8778645E 00	1.6928000E 01	1.0170147E 01
594000.	3.8887973E-12	4.5112764E-13	3.8806318E 00	1.6906000E 01	1.0170147E 01
596000.	3.8038893E-12	4.4069706E-13	3.8833972E 00	1.6884000E 01	1.0170147E 01
598000.	3.7209922E-12	4.3052656E-13	3.8861607E 00	1.6862000E 01	1.0170147E 01
600000.	3.6400543E-12	4.2060913E-13	3.8889222E 00	1.6840000E 01	1.0170147E 01
602000.	3.5609688E-12	4.1112165E-13	3.8907080E 00	1.6826600E 01	1.0170147E 01
604000.	3.4837103E-12	4.0186101E-13	3.8924930E 00	1.6813200E 01	1.0170147E 01
606000.	3.4082344E-12	3.9282153E-13	3.8942772E 00	1.6799800E 01	1.0170147E 01
608000.	3.3344978E-12	3.8399763E-13	3.8960607E 00	1.6786400E 01	1.0170147E 01
610000.	3.2624585E-12	3.7538395E-13	3.8978432E 00	1.6773000E 01	1.0170147E 01
612000.	3.1920736E-12	3.6697503E-13	3.8996251E 00	1.6759600E 01	1.0170147E 01
614000.	3.1233034E-12	3.5876577E-13	3.9014061E 00	1.6746200E 01	1.0170147E 01
616000.	3.0561109E-12	3.5075145E-13	3.9031864E 00	1.6732800E 01	1.0170147E 01
618000.	2.9904551E-12	3.4292684E-13	3.9049657E 00	1.6719400E 01	1.0170147E 01
620000.	2.9263006E-12	3.3520744E-13	3.9067444E 00	1.6706000E 01	1.0170147E 01
622000.	2.8636105E-12	3.2782854E-13	3.9085222E 00	1.6692600E 01	1.0170147E 01
624000.	2.8023482E-12	3.2054548E-13	3.9102992E 00	1.6679199E 01	1.0170147E 01
626000.	2.7424816E-12	3.1343417E-13	3.9120755E 00	1.6665800E 01	1.0170147E 01
628000.	2.6839758E-12	3.0649020E-13	3.9138509E 00	1.6652400E 01	1.0170147E 01
630000.	2.6267982E-12	2.9970942E-13	3.9156256E 00	1.6639000E 01	1.0170147E 01
632000.	2.5709172E-12	2.9308781E-13	3.9173994E 00	1.6625600E 01	1.0170147E 01
634000.	2.5163012E-12	2.8662138E-13	3.9191725E 00	1.6612200E 01	1.0170147E 01
636000.	2.4629205E-12	2.8030636E-13	3.9209448E 00	1.6598800E 01	1.0170147E 01
638000.	2.4107448E-12	2.7413891E-13	3.9227163E 00	1.6585400E 01	1.0170147E 01
640000.	2.3597463E-12	2.6811552E-13	3.9244870E 00	1.6572000E 01	1.0170147E 01
642000.	2.3098961E-12	2.6223255E-13	3.9262570E 00	1.6558600E 01	1.0170147E 01
644000.	2.2611669E-12	2.5648654E-13	3.9280261E 00	1.6545200E 01	1.0170147E 01
646000.	2.2135327E-12	2.5087421E-13	3.9297944E 00	1.6531800E 01	1.0170147E 01
648000.	2.1669686E-12	2.4539216E-13	3.9315620E 00	1.6518400E 01	1.0170147E 01
650000.	2.1214438E-12	2.4003729E-13	3.9333288E 00	1.6505000E 01	1.0170147E 01
652000.	2.0769392E-12	2.3480643E-13	3.9350948E 00	1.6491600E 01	1.0170147E 01
654000.	2.0334294E-12	2.2969662E-13	3.9368601E 00	1.6478200E 01	1.0170147E 01
656000.	1.9908903E-12	2.2470486E-13	3.9386245E 00	1.6464800E 01	1.0170147E 01
658000.	1.9492988E-12	2.1982822E-13	3.9403882E 00	1.6451400E 01	1.0170147E 01
660000.	1.9086335E-12	2.1506403E-13	3.9421511E 00	1.6438000E 01	1.0170147E 01
662000.	1.8688714E-12	2.1040941E-13	3.9439132E 00	1.6424600E 01	1.0170147E 01
664000.	1.8299913E-12	2.0586171E-13	3.9456746E 00	1.6411200E 01	1.0170147E 01
666000.	1.7919739E-12	2.0141848E-13	3.9474352E 00	1.6397800E 01	1.0170147E 01
668000.	1.7547973E-12	1.9707703E-13	3.9491949E 00	1.6384400E 01	1.0170147E 01
670000.	1.7184432E-12	1.9283503E-13	3.9509540E 00	1.6371000E 01	1.0170147E 01
672000.	1.6828913E-12	1.8868995E-13	3.9527123E 00	1.6357600E 01	1.0170147E 01
674000.	1.6481227E-12	1.8463947E-13	3.9544698E 00	1.6344200E 01	1.0170147E 01
676000.	1.6141206E-12	1.8068144E-13	3.9562265E 00	1.6330800E 01	1.0170147E 01
678000.	1.5808652E-12	1.7681344E-13	3.9579825E 00	1.6317400E 01	1.0170147E 01
680000.	1.5483411E-12	1.7303352E-13	3.9597377E 00	1.6304000E 01	1.0170147E 01
682000.	1.5165292E-12	1.6933933E-13	3.9614921E 00	1.6290600E 01	1.0170147E 01
684000.	1.4854140E-12	1.6572893E-13	3.9632458E 00	1.6277200E 01	1.0170147E 01
686000.	1.4549803E-12	1.6220042E-13	3.9649987E 00	1.6263800E 01	1.0170147E 01
688000.	1.4252109E-12	1.5875168E-13	3.9667508E 00	1.6250400E 01	1.0170147E 01
690000.	1.3960912E-12	1.5538089E-13	3.9685022E 00	1.6237000E 01	1.0170147E 01
692000.	1.3676056E-12	1.5208613E-13	3.9702529E 00	1.6223600E 01	1.0170147E 01
694000.	1.3397395E-12	1.4886558E-13	3.9720027E 00	1.6210200E 01	1.0170147E 01
696000.	1.3124794E-12	1.4571757E-13	3.9737518E 00	1.6196800E 01	1.0170147E 01
698000.	1.2858105E-12	1.4264028E-13	3.9755002E 00	1.6183400E 01	1.0170147E 01
700000.	1.2597195E-12	1.3963205E-13	3.9772478E 00	1.6170000E 01	1.0170147E 01

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(2) White Sands Missile Range Reference Atmosphere (Part I), August 1964.

(3) Fort Churchill Missile Range Reference Atmosphere for Fort Churchill, Canada (Part I), December 1964.

(4) Pacific Missile Range Reference Atmosphere for Eniwetok, Marshall Islands (Part I), December 1964.

(5) Fort Greely Missile Range Reference Atmosphere (Part I), November 1964.

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SECTION XV. DISTRIBUTION OF SURFACE EXTREMES IN THE UNITED STATES

By

Glenn E. Daniels

15. 1 Introduction.

In contracts for component parts of space vehicles with contractors located in areas not within the geographical areas covered in the preceding sections of this document, other local environments may require inclusion in the design. Some of these environments will only need consideration in the transporting of the components, others in the fabrication.

15. 2 Environments Included.

(a) Air temperature, extreme maximum and minimum,

(b) Snow fall - snow loads, 24-hour maximum and storm maximum,

(c) Hail, maximum size, and

(d) Atmosphere pressure, extreme maximum and minimum.

15. 3 Source of Data.

The extremes presented have been prepared using all available data from Weather Bureau stations and published articles. These extremes represent the highest or lowest extreme value measured at each station. The length of record varies from station to station, but most values represent more than 15 years of record. Where the local surroundings have a geographical area with a special influence on an extreme value (such as the minimum temperature on a high mountain peak or a local condition), it will not in general be shown on the maps presented unless a first order Weather Bureau station is located there. The usefulness of the maps will not be impaired though, since there will not usually be contractors in these areas who fabricate space vehicle components. If there is a contractor at such a locality and an item of equipment is especially sensitive to an environment, a study of the local environment where fabrication is to be made would be in order.

15.4 Extreme Design Environments.

15.4.1 Air Temperature.

The distribution of extreme maximum air temperature in the United States is shown in Figure 15.1 while Figure 15.2 shows the extreme minimum temperature distribution.

15.4.2 Snow Fall - Snow Load.

The maps in Figures 15.3 and 15.4 show the maximum depth of snow and the corresponding snow loads. Figure 15.3 shows the maximum depth for a 24-hour period; Figure 15.4 shows the maximum depth and the corresponding snow loads for a storm period. The storm total map shows the same snow depth as in the 24-hour map in the Southern areas of the United States since snow storms seldom exceed 24 hours in these areas.

The terrain combined with the general movement of weather patterns has a great effect on the amount of fall, accumulation, and melting of the snow. Also the length of a single storm varies for various areas. In some areas in the mountain regions much greater amounts of snowfall have been recorded than shown on the maps. Also the snow in these areas may remain for the entire winter. For example, in a small valley near Soda Springs, California, a seasonal snow accumulation of 7.9 meters (26 feet) with a density about 0.35 was recorded. This gives a snow load of 2772 kg m^{-2} (567.7 lb ft^{-2}). Such a snow pack can do considerable damage to improperly protected equipment buried deep in the snow. This snow pack at Soda Springs is the greatest of record in the United States and was nearly double previous records in the same area. A study of the maximum snow loads in the Wasatch Mountains of Utah (Ref. 15.1) showed that in a 100 year return period at 2740 m (9000 ft), a snow load of 1220 kg m^{-2} (250 lbs ft^{-2}) could be expected.

15.4.3 Hail.

The distribution of maximum sized hail stones in the United States is shown in Figure 15.5. The sizes are for single hailstones and not conglomerates of several hail stones frozen together.

15.4.4 Atmospheric Pressure.

Atmospheric pressure extremes normally given in the literature are given as the pressure which would have occurred if the station was at sea level.

The surface weather map published by the United States Weather Bureau uses sea level pressures for the pressure values to assist in map analysis and forecasting. These sea level pressure values are obtained from the station pressures by use of the hydrostatic equation:

$$dP = -\rho g dZ$$

where

dP = pressure difference

ρ = density

g = gravity

dZ = altitude difference.

These sea level data are only valid for design purposes at locations with elevation near sea level. As an example, when the highest officially reported sea level pressure observed in the United States of 106330 newtons m^{-2} (1063.3 mb) occurred at Helena, Montana (Ref. 15.2), the actual station pressure was about 92100 newtons m^{-2} (921 mb) because the station is 1187 m (3893 ft) above mean sea level.

Figures 15.6 and 15.7 show the general distribution of extreme maximum and minimum station pressures in the United States.

Because of the direct relationship of pressure and station elevation, Figures 15.8 through 15.11 should be used with the station elevation to obtain the extreme maximum and minimum pressure values for any location in the United States. Similar maps and graphs in U. S. Customary Units are given in Reference 15.3. Table 15.1 gives a list of the station elevations for a number of locations in the United States. These are elevations of the barometer at the Weather Bureau Office.

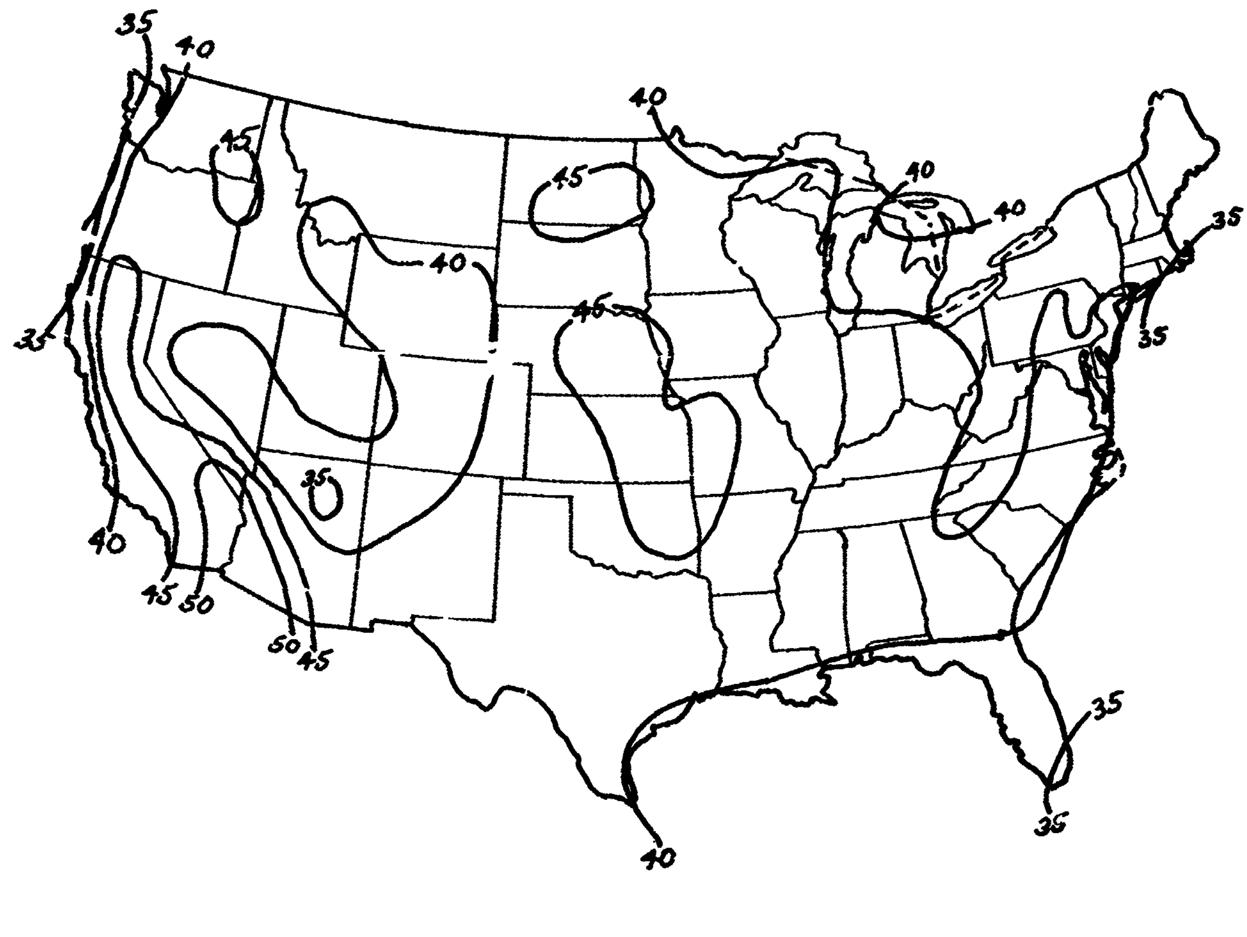


FIGURE 15.1 EXTREME MAXIMUM TEMPERATURE (degrees Celsius)

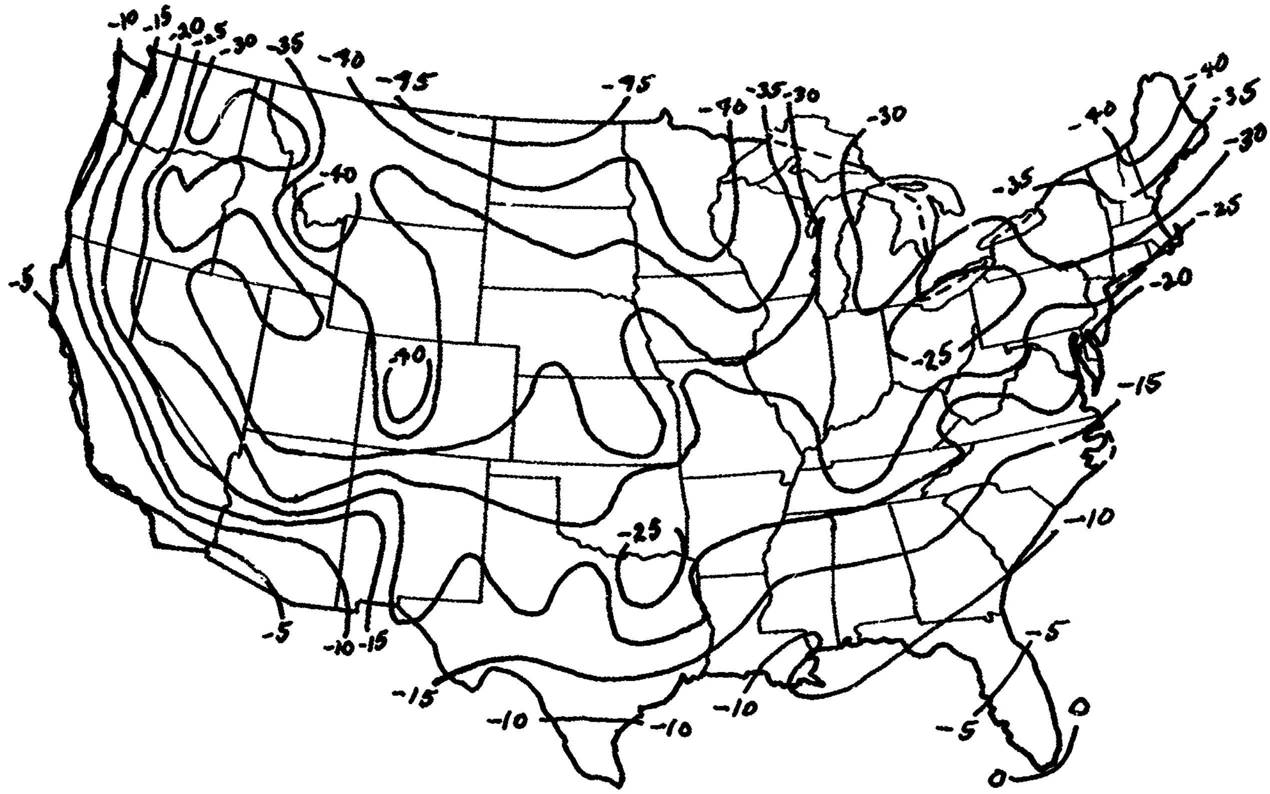


FIGURE 15.2 EXTREME MINIMUM TEMPERATURE (degrees Celsius)

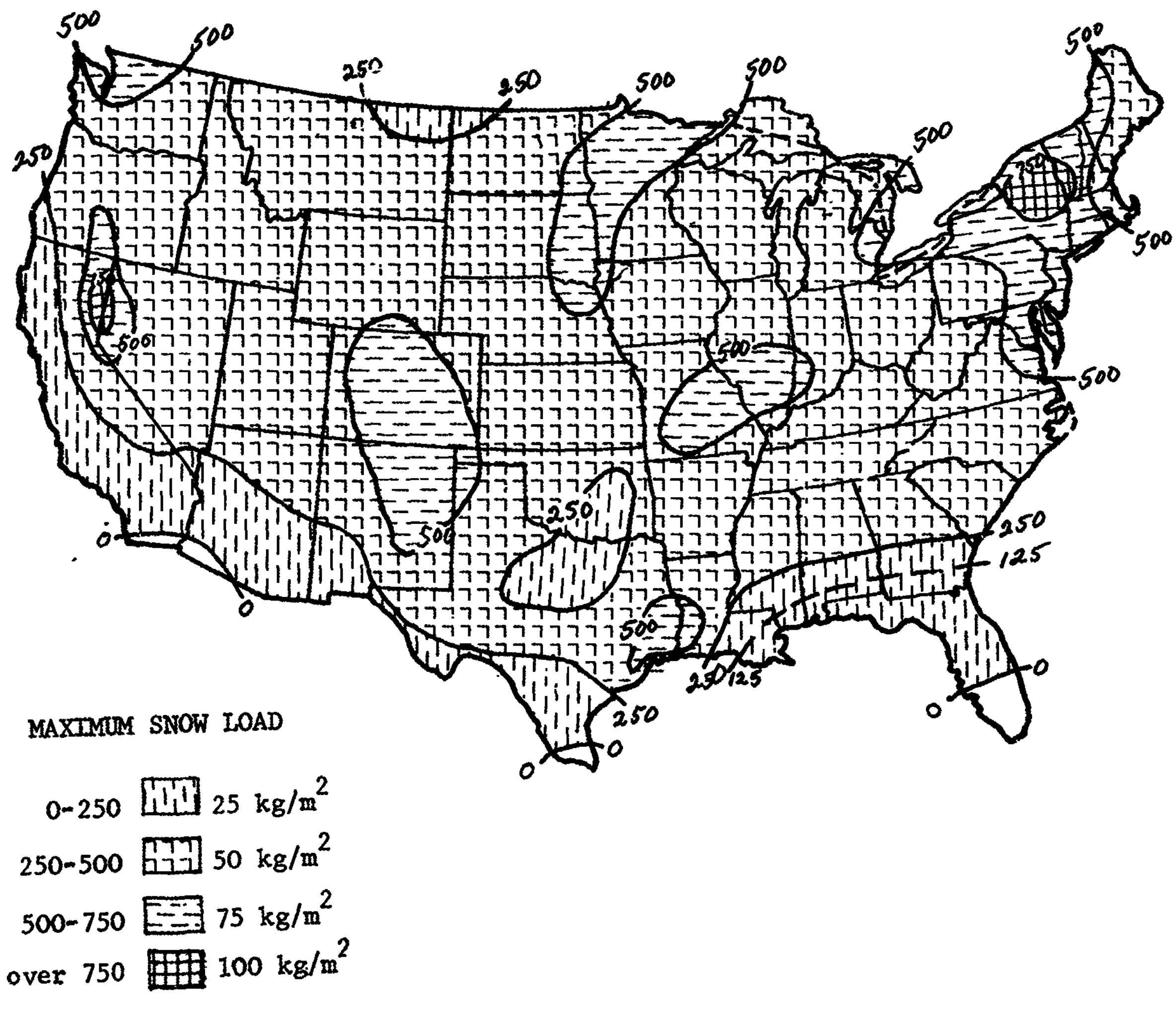


FIGURE 15.3 EXTREME 24-HOUR MAXIMUM SNOW FALL (MILLIMETERS)

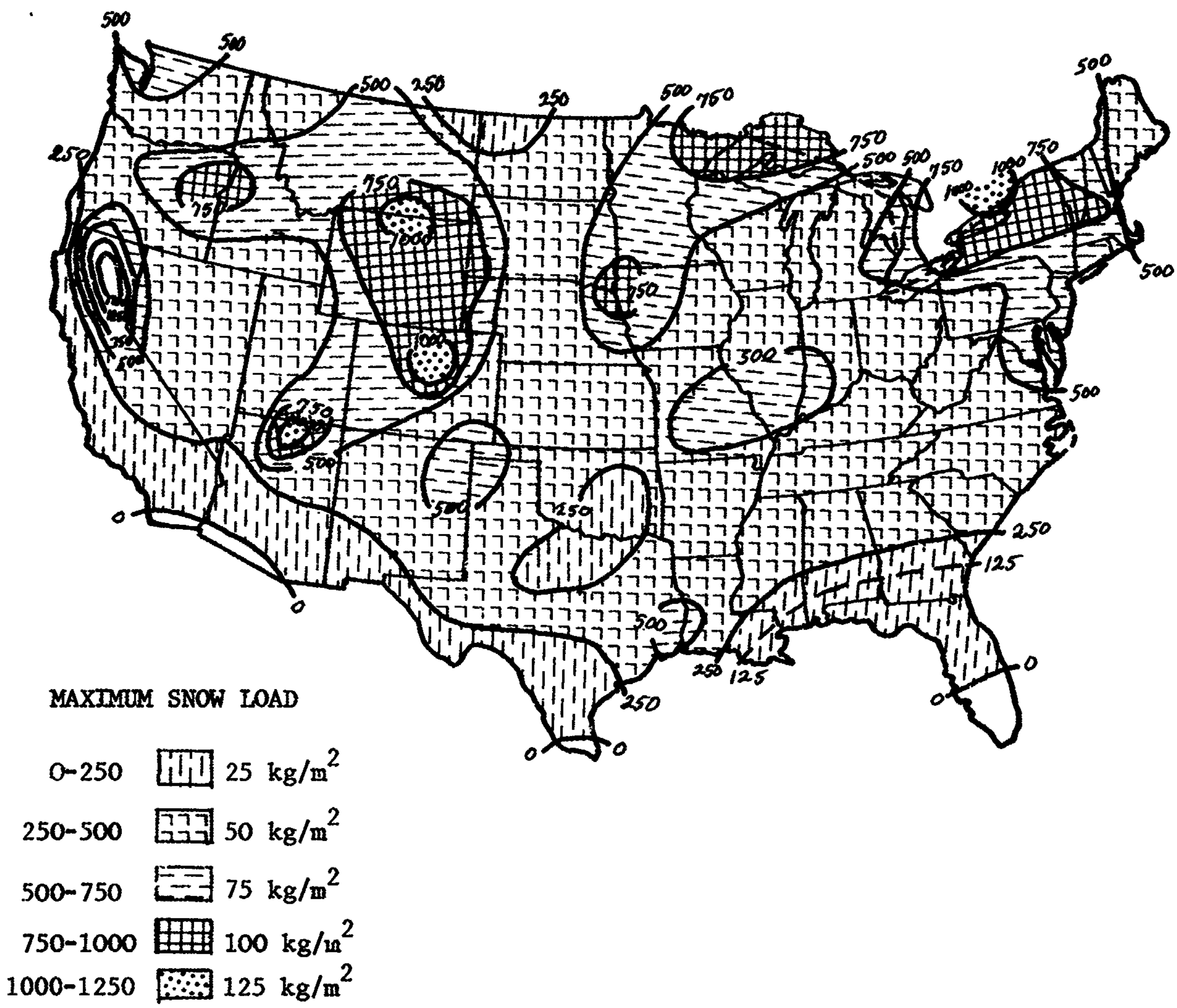


FIGURE 15.4 EXTREME STORM MAXIMUM SNOW FALL (MILLIMETERS)

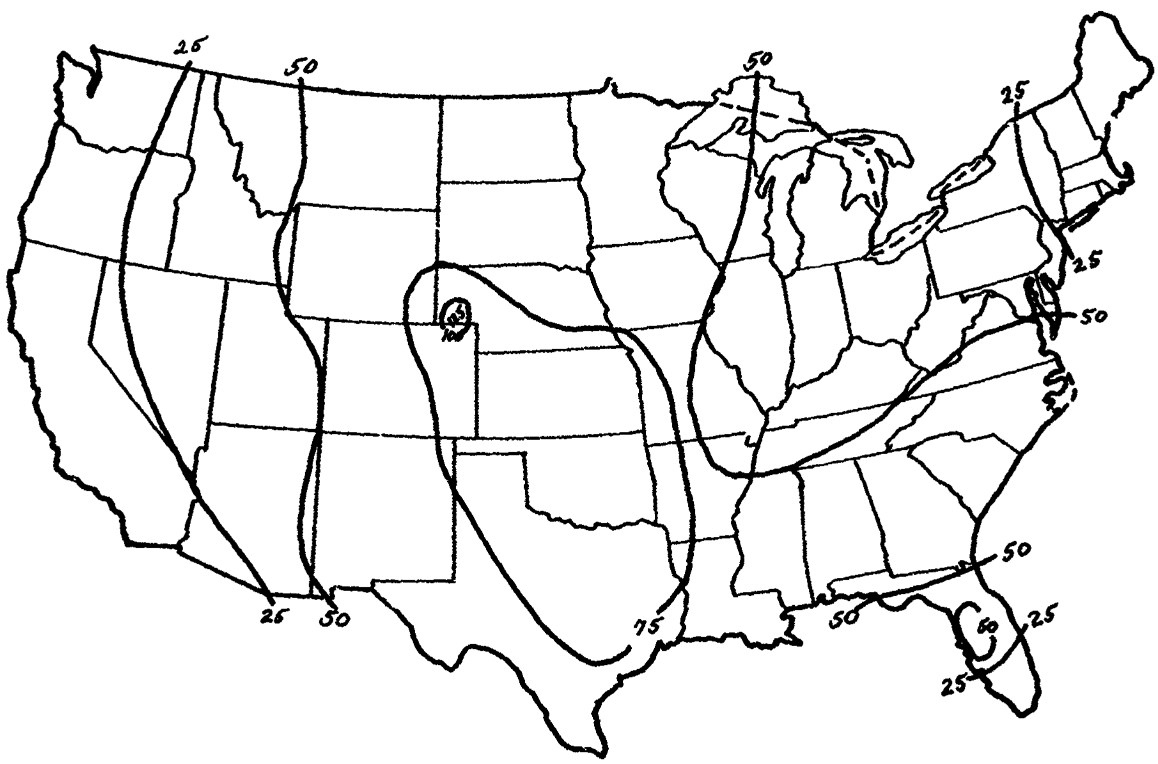


FIGURE 15.5 EXTREME MAXIMUM HAIL STONE DIAMETERS (MILLIMETERS)

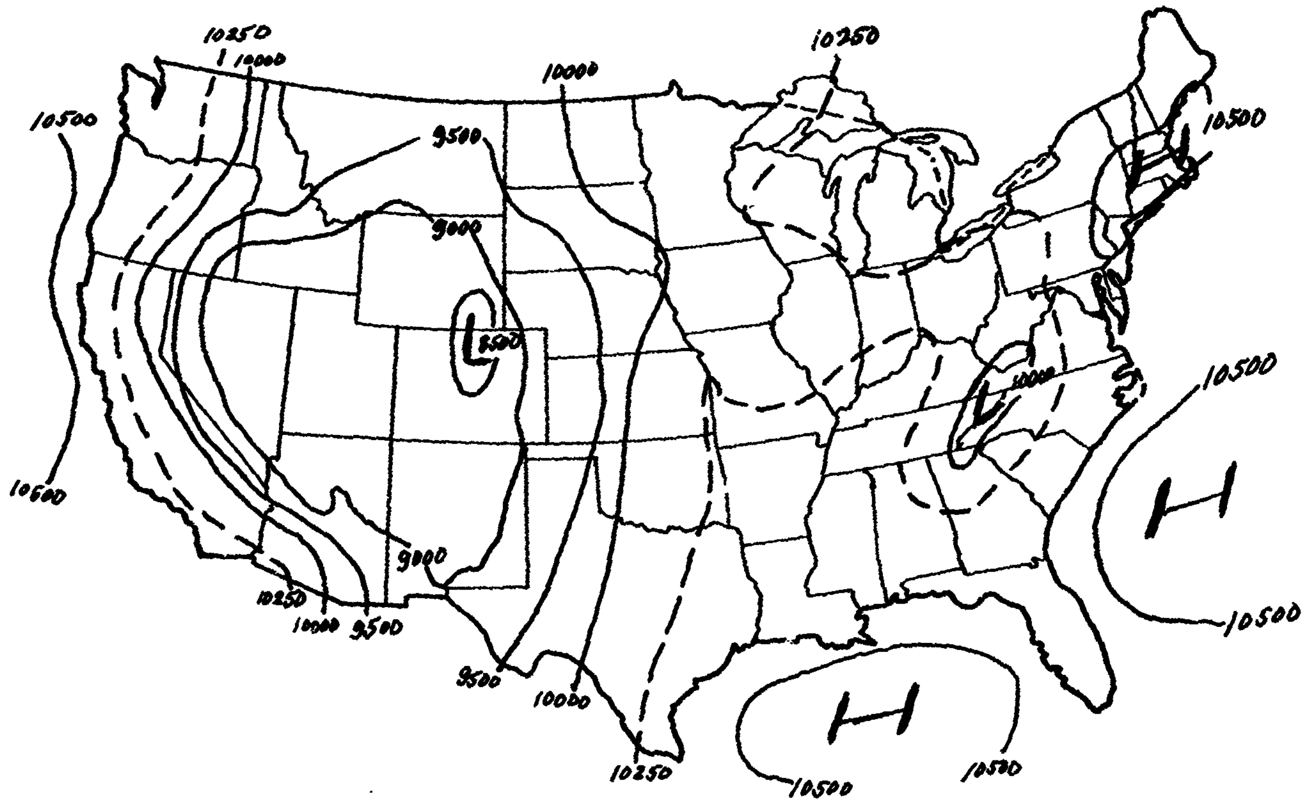


FIGURE 15.6 MAXIMUM ABSOLUTE STATION PRESSURE (Newton/m^2)

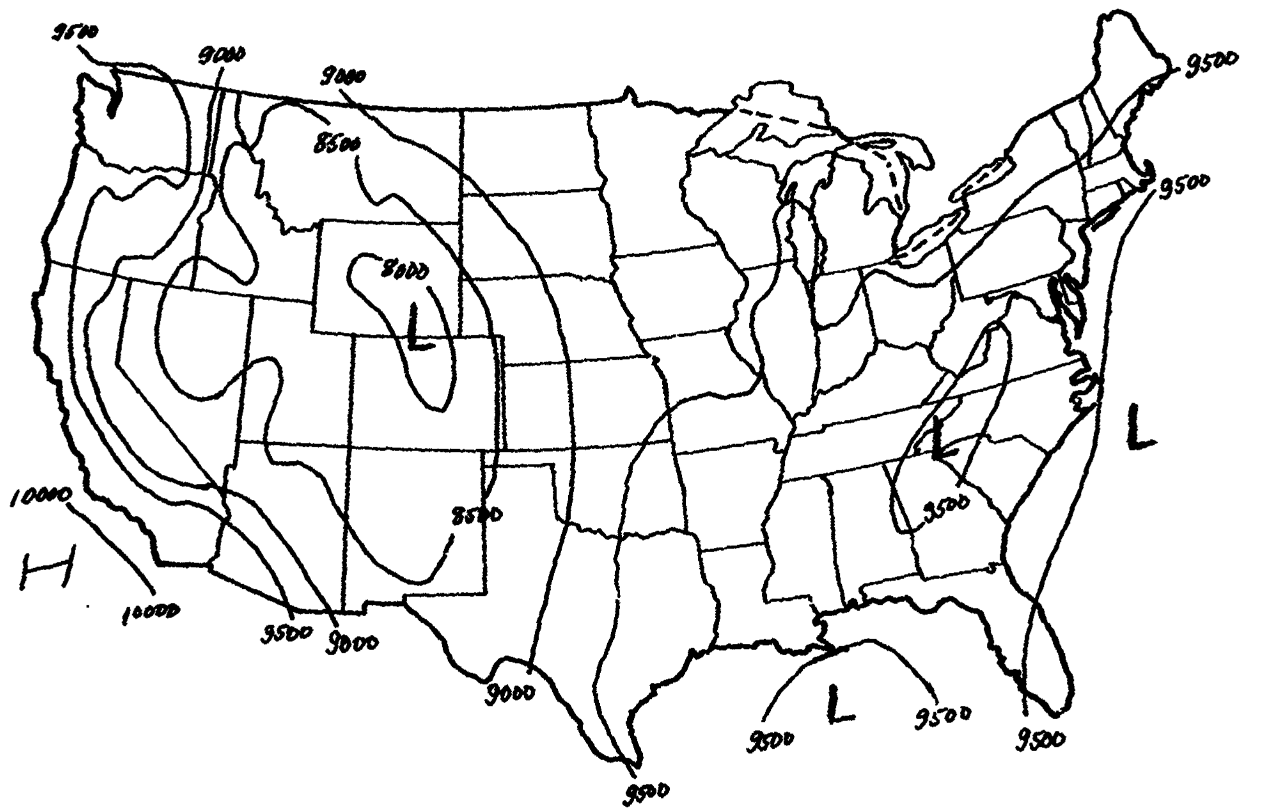


FIGURE 15.7 MINIMUM ABSOLUTE STATION PRESSURE (Newton/m^2)

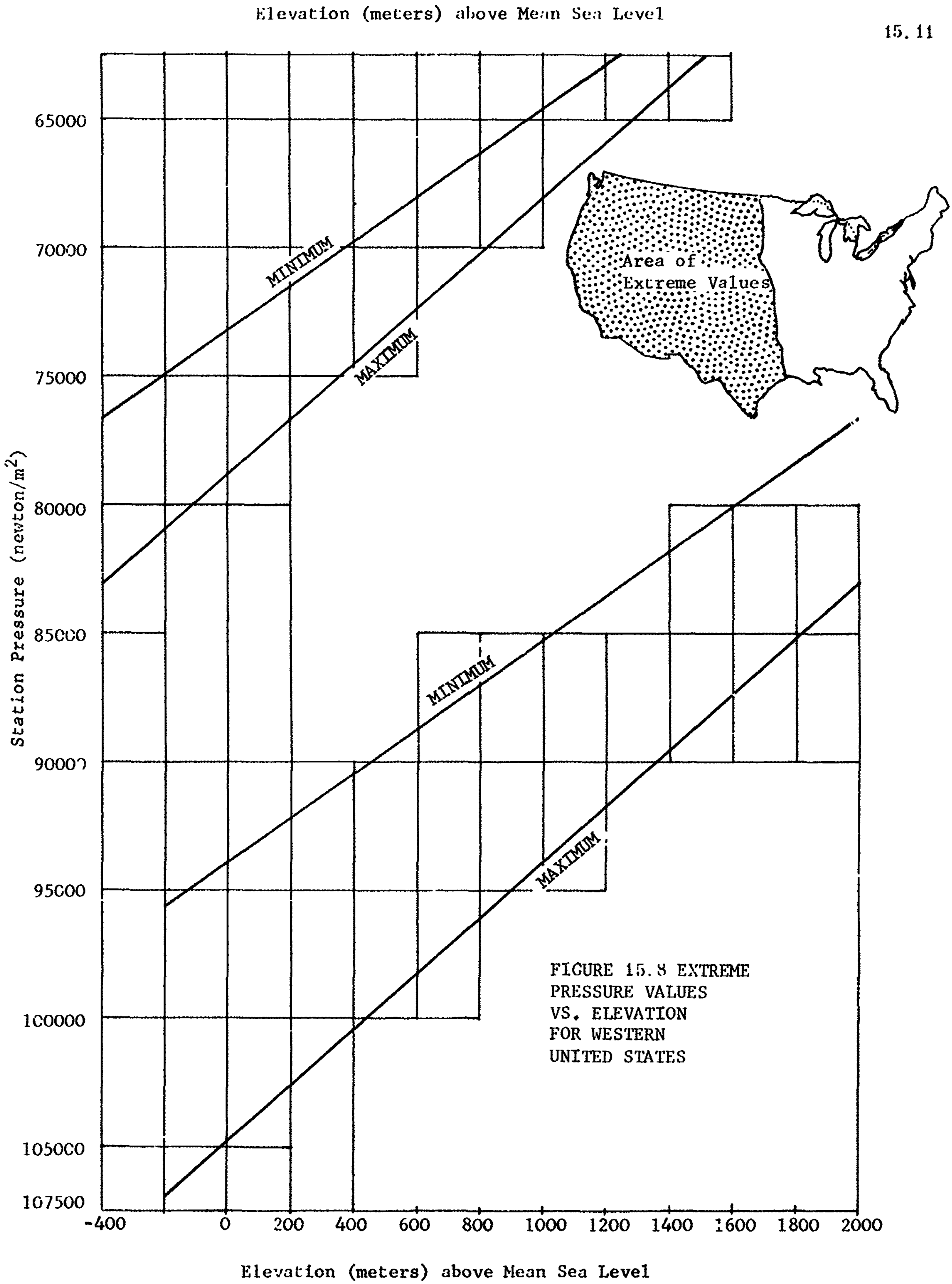
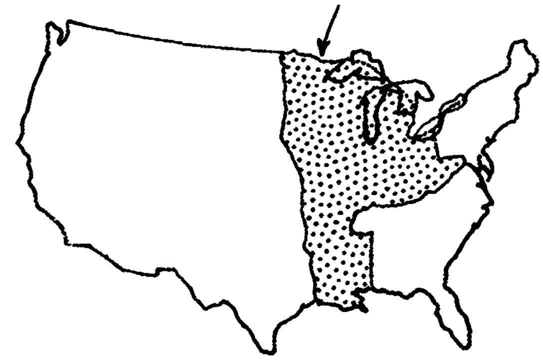
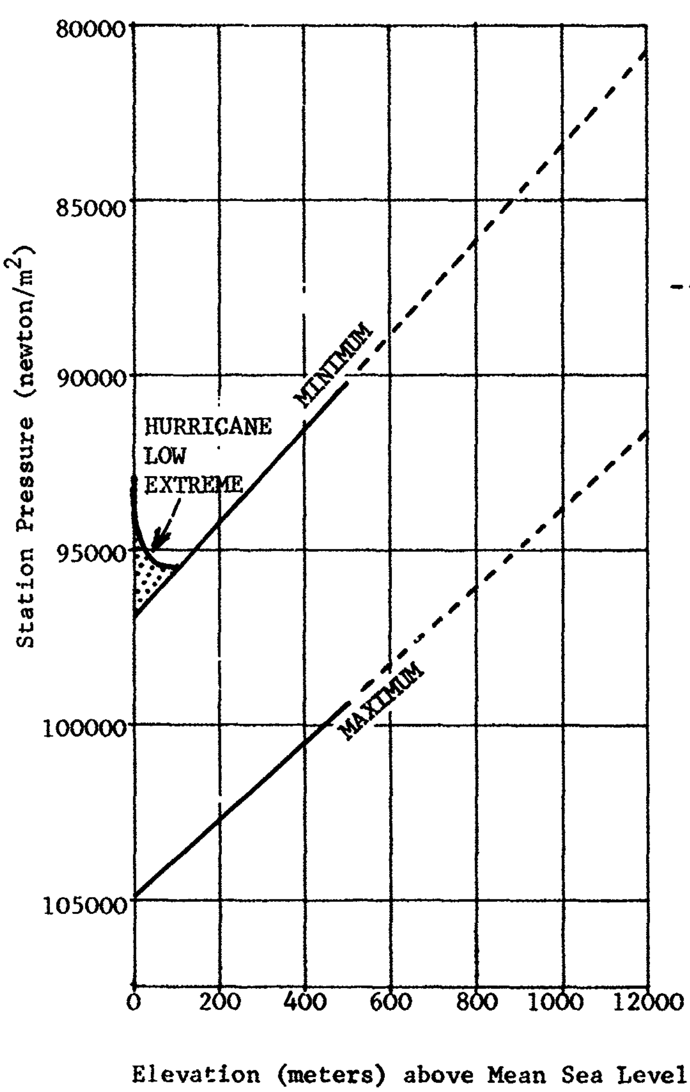


FIGURE 15.8 EXTREME PRESSURE VALUES VS. ELEVATION FOR WESTERN UNITED STATES





----- Extrapolated Data

FIGURE 15.9 EXTREME PRESSURE VALUES VS. ELEVATION FOR CENTRAL UNITED STATES

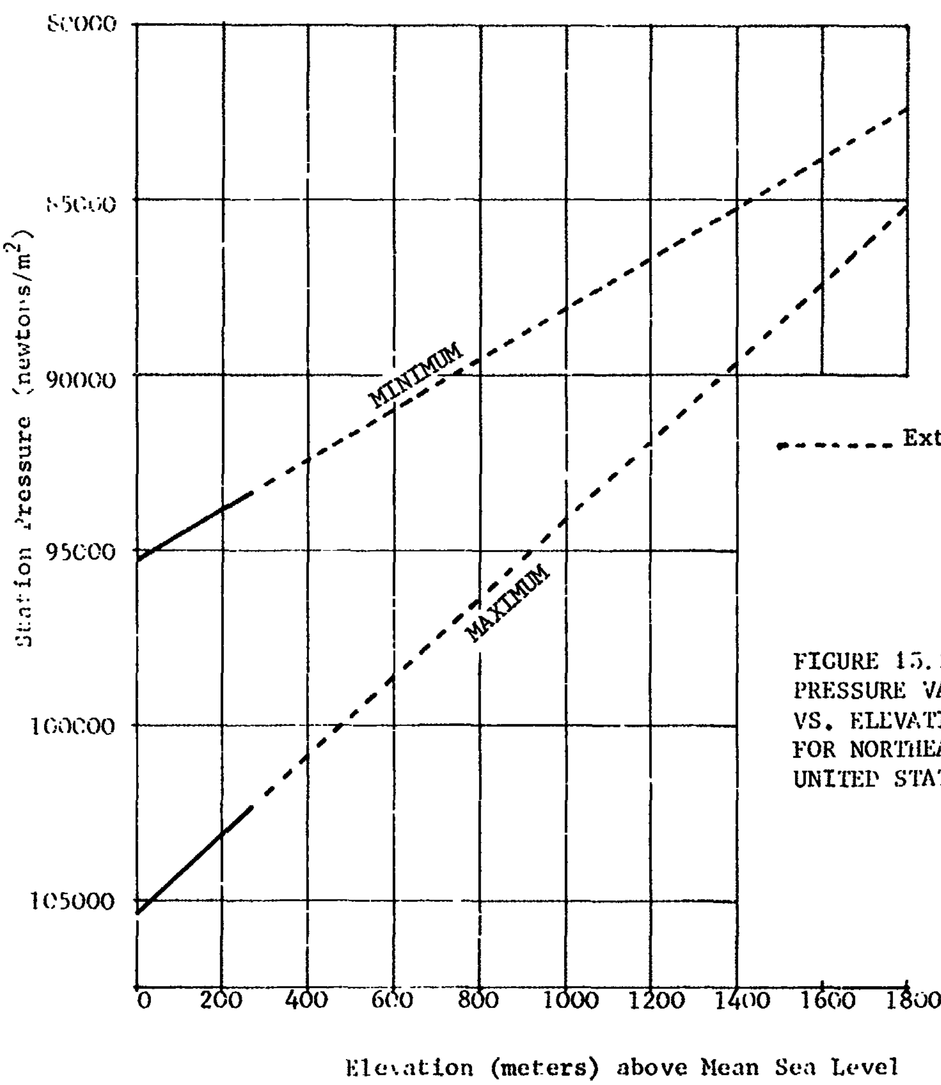
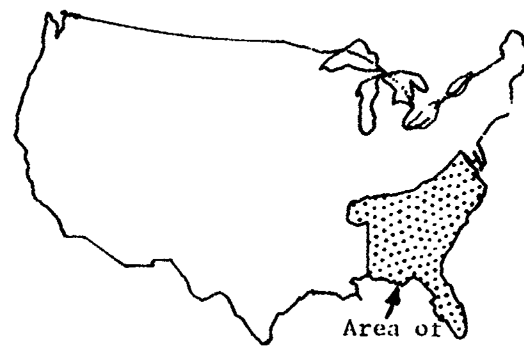


FIGURE 15.10 EXTREME
PRESSURE VALUES
VS. ELEVATION
FOR NORTHEASTERN
UNITED STATES



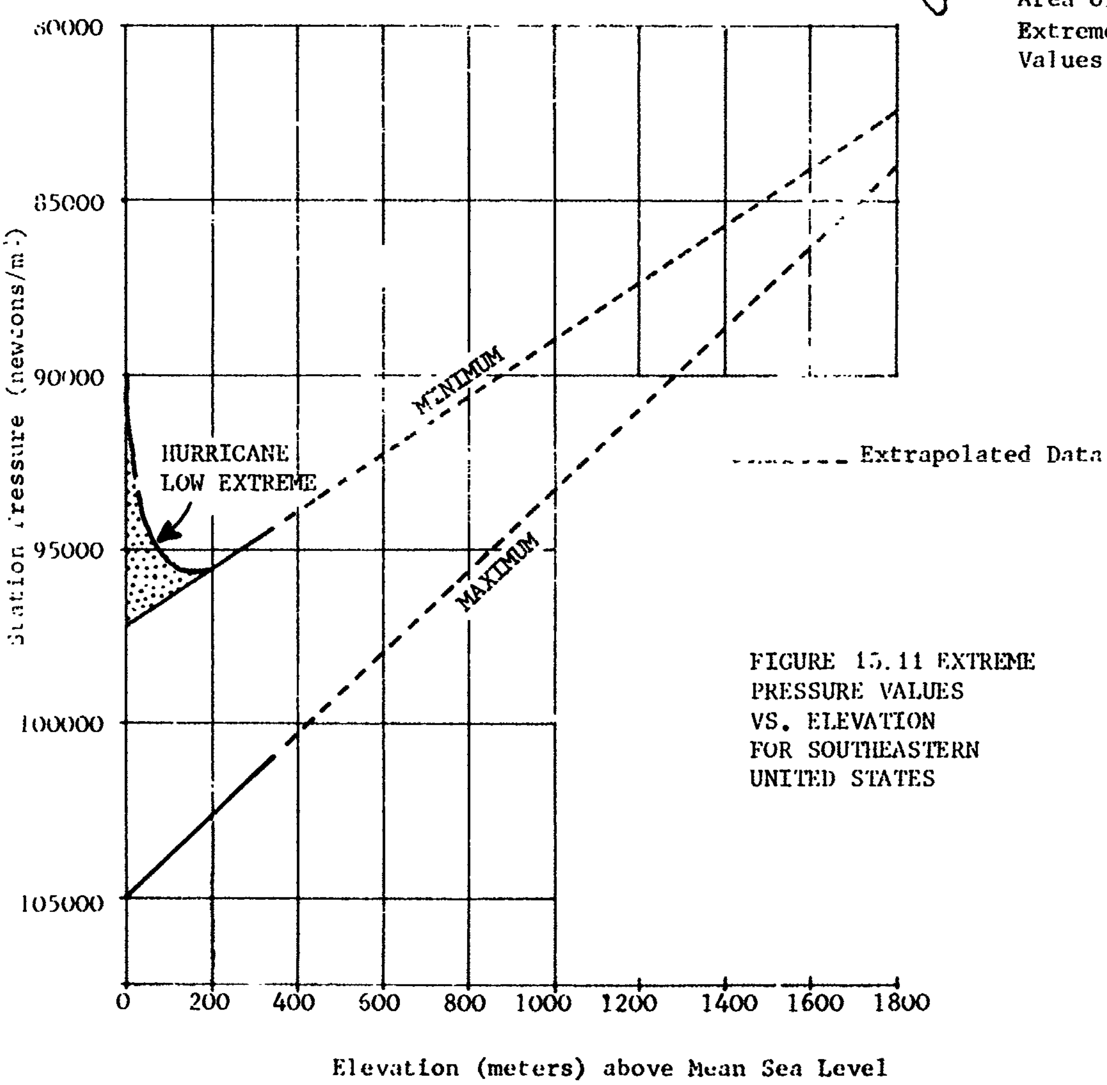


FIGURE 15.11 EXTREME PRESSURE VALUES VS. ELEVATION FOR SOUTHEASTERN UNITED STATES

TABLE 15.1 ELEVATIONS OF CITIES OF THE UNITED STATES

(Values are elevation of barometer at U. S. Weather Bureau Station)

Location	Elevation, M3L (feet)	(meters)
ALABAMA		
Birmingham	610	185.9
Mobile	211	34.3
ARIZONA		
Phoenix	1100	335.2
Yuma	19[illegible]	60.7
ARKANSAS		
Fort Smith	499	152.1
Little Rock	257	78.2
Texarkana	361	110.0
CALIFORNIA		
Eureka	43	13.1
Fresno	331	100.9
Los Angeles	312	95.1
Sacramento	20	6.1
San Diego	19	5.8
San Francisco	52	15.8
COLORADO		
Denver	5292	1613.9
Grand Junction	4849	1478.0
Pueblo	4639	1414.0
CONNECTICUT		
Hartford	15	4.6
New Haven	6	1.8
DISTRICT OF COLUMBIA		
Washington	72	21.9
FLORIDA		
Apalachicola	13	4.0
Fort Myers	15	4.6
Jacksonville	18	5.5
Key West	5	1.5
Miami	7	2.1
Pensacola	13	4.0
GEORGIA		
Atlanta	1054	321.3
Savannah	48	14.6
IDAHO		
Boise	2842	866.2
Pocatello	4444	1354.5
ILLINOIS		
Cairo	314	95.7
Chicago	610	185.9
Springfield	587	178.9
INDIANA		
Evansville	383	116.7
Indianapolis	718	218.8
IOWA		
Des Moines	807	246.0
Sioux City	1094	333.4
KANSAS		
Dodge City	2594	790.7
Goodland	3645	1111.0
Wichita	1321	402.6
KENTUCKY		
Louisville	457	139.3
LOUISIANA		
Lake Charles	12	3.7
New Orleans	3	0.9
Shreveport	174	53.0
MAINE		
Caribou	624	190.2
Portland	6[illegible]	18.6
MARYLAND		
Baltimore	14	4.3
MASSACHUSETTS		
Boston	15	4.6
Nantucket	43	13.1
MICHIGAN		
Alpena	587	178.9
Detroit	619	188.7
Marquette	677	206.3
Sault Ste. Marie	721	219.8
MINNESOTA		
Duluth	1162	354.2
International Falls	1[illegible]79	359.4
Minneapolis	830	253.0
MISSISSIPPI		
Jackson	305	93.0
MISSOURI		
Kansas City	741	225.9
St. Louis	809	246.6
MONTANA		
Havre	2488	758.3
Helena	3893	1186.6
NEBRASKA		
Omaha	978	298.1
NEVADA		
Elko	5075	1546.9
Las Vegas	2162	659.0
Winnemucca	4299	1310.3
New Hampshire		
Concord	339	103.3
NEW JERSEY		
Atlantic City	10	3.0
Newark	11	3.4
Trenton	56	17.1
NEW YORK		
Albany	19	5.8
Buffalo	693	211.2
New York City	10	3.0
Rochester	543	165.5
Syracuse	424	129.2
NORTH CAROLINA		
Cape Hatteras	7	2.1
Raleigh	400	121.9
Wilmington	30	9.1
NORTH DAKOTA		
Fargo	900	274.3
Bismarck	1650	502.9
Williston	1877	572.1

TABLE 15.1 (Concluded)

Location	Elevation, MSL (feet)	Elevation, MSL (meters)
OHIO		
Cincinnati	553	168.6
Cleveland	653	199.0
Columbus	724	220.7
Toledo	676	206.0
OKLAHOMA		
Oklahoma City	1254	382.2
Tulsa	672	205.2
OREGON		
Medford	1312	399.9
Pendleton	1492	454.8
Portland	21	6.4
Roseburg	479	146.0
PENNSYLVANIA		
Harrisburg	335	102.1
Philadelphia	7	2.1
Pittsburg	749	228.3
RHODE ISLAND		
Block Island	110	33.5
Providence	12	3.7
SOUTH CAROLINA		
Charleston	9	2.7
Columbia	217	66.1
Greenville	1018	310.3
SOUTH DAKOTA		
Huron	1282	390.8
Rapid City	3165	964.7
Sioux Falls	1420	432.8
TENNESSEE		
Chattanooga	670	204.2
Memphis	263	80.2
Nashville	577	175.9
TEXAS		
Abilene	1759	536.1
Amarillo	3590	1094.2
Brownsville	16	4.9
Corpus Christi	43	13.1
Dallas	476	145.1
El Paso	3920	1194.6
Galveston	5	1.5
San Antonio	792	241.4
Wichita Falls	1002	305.4
UTAH		
Salt Lake City	4220	1286.3
VERMONT		
Burlington	331	100.9
VIRGINIA		
Norfolk	11	3.4
Richmond	162	49.4
WASHINGTON		
Tatoosh Island	101	30.8
Seattle	14	4.3
Spokane	2357	718.4
Walla Walla	949	289.3
WEST VIRGINIA		
Charleston	950	289.6
WISCONSIN		
Green Bay	689	210.0
La Crosse	652	198.7
Madison	857	261.2
Milwaukee	620	189.0
WYOMING		
Casper	5319	1621.2
Cheyenne	6131	1868.7
Lander	5563	1695.6
Sheridan	3942	1201.5

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17.10

TMX-53328 APPROVAL May 1, 1966

TERRESTRIAL ENVIRONMENT (CLIMATIC) CRITERIA GUIDELINES FOR USE IN SPACE VEHICLE DEVELOPMENT, 1966 REVISION

By

Glenn E. Daniels
James R. Scoggins
and
Orvel E. Smith

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Office. This report, in its entirety, has been determined to be unclassified.

William W. Vaughan

WILLIAM W. VAUGHAN
Chief, Aerospace Environment Division

Geissler

E. D. GEISSLER
Director, Aero-Astrodynamics Laboratory